PALÆONTOLOGIA INDICA.

(SER. I, III, V, VI, VIII.)—CRETACEOUS FAUNA OF SOUTHERN INDIA, *by* F. STOLICZKA, *except* VOL. I, PT. I, *by* H. F. BLANFORD.

SER. I & III.—VOL. I. The Cephalopoda (1861-65), pp. 216, pls. 94 (6 double) (*out of print*).

V.—VOL. II. The Gastropoda (1867-68), pp. xiii, 500, pls. 28 (*out of print*).

VI.—VOL. III. The Pelecypoda (1870-71), pp. xxii, 537, pls. 50.

VIII.—VOL. IV. The Brachiopoda, Ciliopoda, Echinodermata, Corals, etc. (1872—73), pp. v, 202, pls. 29.

(SER. II, XI, XII.)—THE FOSSIL FLORA OF THE GONDWANA SYSTEM, *by* O. FEISTMANTEL, *except* VOL. I, PT. 1, *by* T. OLDHAM and J. MORRIS.

VOL. I, pp. xviii, 233, pls. 72, 1863-79. Pt. 1 (*out of print*): Rájmahál Group Rájmahal Hill. Pt. 2: *The same* (*continued*). Pt. 3: Plants from Golapilli. Pt. 4: Outliers on the Madras Coast.

VOL. II, pp. xli, 115, pls. 26, 1876-78. Pt. 1: Jurassic Flora of Kach. Pt. 2: Flora of the Jabalpur group.

VOL. III, pp. xi, 64 + 149, pls. 80 (9 double) (I-XXXI + IA—XLVIIA). 1879-81. Pt. 1: The Flora of the Talchir-Karharbari beds. Pt. 2: The Flora of the Damuda and Panchet Divisions. Pt. 3: *The same* (*concluded*).

VOL. IV, pp. xxvi, 25 + 66, pls. 35 (2 double) (I—XXI + IA—XIVA). Pt. 1 (1882) (*out of print*): Fossil Flora of the South Rewah Gondwana basin. Pt. 2 (1886); Fossil Flora of some of the coal-fields in Western Bengal.

(SER. IX.)—JURASSIC FAUNA OF KUTCH.

VOL. I, (1873-76). The Cephalopoda, pp. i, 247, pls. 60 (6 double), by W. WAAGEN.

VOL. II, pt. I (1893). The Echinoidea of Kach, pp. 12, pls. 2, by J. W. GREGORY (*out of print*):

VOL. II, pt. 2 (1900). The Corals, pp. 196, I-IX, pls. 26, by J. W. GREGORY.

VOL. III, pt. I (1900). The Brachiopoda, pp. 87, pls. 15, by F. L. KITCHIN.

VOL. III, pt. 2 (1903). Lamellibranchiata: Genus Trigonia, pp. 122, pls. 10, by F. L. KITCHIN.

(SER. IV.)—INDIAN PRE-TERTIARY VERTEBRATA.

VOL. I, pp. vi, 137, pls. 26. 1865-85. Pt. 1 (1865): The Vertebrate Fossils from the Panchet rocks, by T. H. HUXLEY. Pt. 2 (1878): The Vertebrate Fossils of the Kota-Maleri Group, by SIR P. DE M. GREY EGERTON, L. C. MIALL and W. T. BLANFORD. Pt. 3 (1879): Reptilia and Batrachia, by R. LYDEKKER. Pt. 4 (1885) (*out of print*): The Labyrinthodont from the Bijori group, by R. LYDEKKER. Pt. 5 (1885) (*out of print*): The Reptilia and Amphibia of the Maleri and Denwa groups, by R. LYDEKKER.

(SER. X.)—INDIAN TERTIARY AND POST-TERTIARY VERTEBRATA, *by* R. LYDEKKER, *except* VOL. I, PT. I, by R. B. FOOTE.

VOL. I, pp. xxx, 300, pls. 50. 1874-80. Pt. 1: Rhinoceros deccanensis. Pt. 2: Molar teeth and other remains of Mammalia. Pt. 3: Crania of Ruminants. Pt. 4: Supplement to Pt. 3. Pt. 5: Siwalik and Narbada Proboscidia.

VOL. II, pp. xv, 363, pls. 45. 1881-84. Pt. 1: Siwalik Rhinocerotidæ. Pt. 2: Supplement to Siwalik and Narbada Proboscidia. Pt. 3: Siwalik and Narbada Equidæ. Pt. 4: Siwalik Camelopardalidæ. Pt. 5: Siwalik Selenodont Suina, etc. Pt. 6: Siwalik and Narbada Carnivora.

VOL. III, pp. xxiv, 264, pls. 38. 1884-86. Pt. 1 (*out of print*): Additional Siwalik Perissodactyla and Proboscidia. Pt. 2 (*out of print*): Siwalik and Narbada Bunodont Suina. Pt. 3 (*out of print*): Rodents and new Ruminants from the Siwaliks. Pt. 4 (*out of print*): Siwalik Birds. Pt. 5 (*out of print*): Mastodon Teeth from Perim Island. Pt. 6 (*out of print*): Siwalik and Narbada Chelonia. Pt. 7 (*out of print*): Siwalik Crocodilia, Lacertilia and Ophidia. Pt. 8 (*out of print*): Tertiary Fishes.

VOL. IV, pt. 1 (*out of print*), 1886, pp. 18, pls. 6. Siwalik Mammalia (Supplement).

Vol. IV, pt. 2 (*out of print*), 1886, pp. 40 (19—58), pls. 5 (vii—xi). **The Fauna of the Karnul caves (and addendum to pt. 1).**

Vol. IV, pt. 3 (*out of print*), 1887, pp. 7 (59—65), pls. 2 (xii—xiii). **Eocene Chelonia from the Salt-range.**

(Ser. VII, XIV.)—TERTIARY AND UPPER CRETACEOUS FAUNA OF WESTERN INDIA, *by* P. MARTIN DUNCAN *and* W. PERCEY SLADEN, *except* Pt. 1, *by* F. STOLICZKA.

Vol. I, pp. 16+110+382+91=599, pls. 5+28+58+13=104. 1871-85. Pt. 1 (*out of print*): Tertiary Crabs from Sind and Kach. Pt. 1 (new 2): Sind Fossil Corals and Alcyonaria; by P. Martin Duncan. Pt. 3: The Fossil Echinoidea of Sind: *Fas. 1, The Cardita beaumonti* beds; *Fas. 2*, The Ranikot Series in Western Sind; *Fas. 3*, The Khirthar Series; *Fas. 4*, The Nari (Oligocene) Series; *Fas. 5*, The Gaj (Miocene) Series; *Fas. 6*, The Makrán (Pliocene) Series; by Duncan and Sladen. Pt. 4: The Fossil Echinoidea of Kach and Kattywar; by Duncan, Sladen and Blanford.

(Ser. XIII.)—SALT-RANGE FOSSILS, *by* WILLIAM WAAGEN, Ph.D.

Productus-Limestone Group: Vol. I, pt. 1 (1879). Pisces, Cephalopoda, pp. 72, pls. 6.
" " " " 2 (1880). Gastropoda and supplement to pt. 1, pp. 111 (73—183), pls. 10 (1 double), (vii—xvi).
" " " " 3 (1881). Pelecypoda, pp. 144 (185—328), pls. 8 (xvii—xxiv).
" " " " 4 (1882—85). Brachiopoda, pp. 442 (329—770), pls. 62 (xxv—lxxxvi).
" " " " 5 (1885). Bryozoa- Annelida- Echinodermata, pp. 64 (771—834), pls. 10 (lxxxvii—xcvi).
" " " " 6 (1886). Coelenterata, pp. 90 (835—924), pls. 20 (xcvii—cxvi).
" " " " 7 (1887). Coelenterata, Protozoa, pp. 74 (925—998), pls. 12 (cxvii—cxxviii).

Fossils from the Ceratite Formation: Vol. II, pt. 1 (1895). (Pisces— Ammonoidea, pp. 324, pls. 40 (*out of print*).

Geological Results: Vol. IV, pt. 1 (1889), pp. 1—88, pls. 4 (*out of print*).
" " " " 2 (1891), pp. 89—242, pls. 8 (*out of print*).

(Ser. XV.)—HIMALAYAN FOSSILS.

Upper-triassic and liassic fauna of the exotic blocks of Malla Johar in the Bhot Mahals of Kumaon: Vol. I, pt. 1 (1908), pp. 100, pls. 16 (1 double), by Dr. C. Diener.

Anthracolithic Fossils of Kashmir and Spiti: Vol. I, pt. 2 (1899), pp. 96, pls. 8, by Dr. C. Diener.

The Permocarboniferous Fauna of Chitichun No. 1: Vol. I, pt. 3 (1897), pp. 105, pls. 13, by Dr. C. Diener.

The Permian Fossils of the Productus Shales of Kumaon and Garhwal: Vol. I, pt. 4 (1897), pp. 54, pls. 5, by Dr. Diener.

The Permian Fossils of the Central Himalayas: Vol. I, pt. 5 (1903), pp. 204, pls. 10, by Dr. C. Diener.

The Cephalopoda of the Lower Trias: Vol. II, pt. 1 (1897), pp. 182, pls. 23, by Dr. C. Diener.

The Cephalopoda of the Muschelkalk: Vol. II, pt. 2 (1895), pp. 118, pls. 31, by Dr. C. Diener.

Upper Triassic Cephalopoda Fauna of the Himalaya: Vol. III, pt. 1 (1899), pp. 157, pls. 22, by Dr. E. von Mojsisovics.

Trias Brachiopoda and Lamellibranchiata: Vol. III, pt. 2 (1899), pp. 76, pls. 12 (2 double), by Alexander Bittner.

The Fauna of the Spiti Shales: Vol. IV. Cephalopoda: Fasc. 1 (1903), pp. 132, pls. 18; Fasc. 2 (1910), pp. 133—306, pls. 47 (2 double); Fasc. 3 (1910), pp. 307—395, pls. 32; by Dr. V. Uhlig. Lamellibranchiata and Gastropoda: Fasc. 4 (1913), pp. 397—456, pls. 7; by Dr. K. Holdhaus. Additional Notes on the Fauna of the Spiti Shales: Fasc. 5 (1914), pp. 457—511, pls. 4; by Miss Paula Steiger, Ph.D.

The Fauna of the Tropites-Limestone of Byans: Vol. V, Memoir No. 1 (1906), pp. 201, pls. 17 (1 double), by Dr. C. Diener.

The Fauna of the Himalayan Muschelkalk: Vol. V, Memoir No. 2 (1907), pp. 140, pls. 17 (2 double), by Dr. C. Diener.

Ladinic, Carnic and Noric faunæ of Spiti: Vol. V, Memoir No. 3 (1908), pp. 157, pls. 24 (3 double), by Dr. C. Diener.
Lower Triassic Cephalopoda from Spiti, Malla Johar and Byans: Vol. VI, Memoir No. 1 (1909), pp. 186, pls. 31, by Drs. A. von Kraft and C. Diener.
The Fauna of the Traumatocrinus Limestone of Painkhanda: Vol. VI, Memoir No. 2 (1909), pp. 39, pls. 5, by Dr. C. Diener.
The Cambrian Fossils of Spiti: Vol. VII, Memoir No. 1 (1910), pp. 70, pls. 6, by F. R. C. Reed.
Ordovician and Silurian fossils from the Central Himalayas: Vol. VII, Memoir No. 2 (1912), pp. 168, pls. 20, by F. R. C. Reed.

(SER. XVI.)—BALUCHISTAN FOSSILS, *by* FRITZ NOETLING, PH.D., F.G.S.

The Fauna of the Kellaways of Mazár Drik: Vol. I, pt. 1 (1895), pp. 22, pls. 13.
The Fauna of the (Neocomian) Belemnite Beds: Vol. I, pt. 2 (1897), pp. 6, pls. 2 (*out of print*).
The Fauna of the Upper Cretaceous (Maëstrichtien) Beds of the Mari Hills: Vol. I, pt. 3 (1897), pp. 79, pls. 23 (*out of print*).

The price fixed for these publications is four annas per single plate, with a minimum charge of Re. 1.

(NEW SERIES.)

The Cambrian Fauna of the Eastern Salt-range: Vol. I, Memoir 1 (1899), pp. 14, pl. 1, by K. Redlich. Price 1 Re.
Notes on the Morphology of the Pelecypoda: Vol. I, Memoir 2 (1899), pp. 58, pls. 4, by Dr. Fritz Noetling. Price 1 Re. 4 As.
Fauna of the Miocene Beds of Burma: Vol. I, Memoir 3 (1901), pp. 378, pls. 25, by Dr. Fritz Noetling. Price 6 Rs. 4 As. (*out of print*).
Observations sur quelques Plantes Fossiles des Lower Gondwanas: Vol. II, Memoir 1 (1902), pp. 39, pls. 7, by R. Zeiller. Price 1 Re. 12 As.
Permo-Carboniferous Plants and Vertebrates from Kashmir: Vol. II, Memoir No. 2 (1905), pp. 13, pls. 3, by A. C. Seward and Dr. A. Smith Woodward. Price 1 Re.
The Lower Palæozoic Fossils of the Northern Shan States, Upper Burma: Vol. II, Memoir No. 3 (1906), pp. 154, pls. 8, by F. R. C. Reed. Price 2 Rs.
The Fauna of the Napeng Beds or the Rhætic Beds of Upper Burma: Vol. II, Memoir No. 4 (1908), pp. 88, pls. 9, by Miss M. Healey. Price 2 Rs. 4 As.
The Devonian Faunas of the Northern Shan States: Vol. II, Memoir No. 5 (1908), pp. 183, pls. 20, by F. R. C. Reed. Price 5 Rs.
The Mollusca of the Ranikot Series: Vol. III, Memoir No. 1 (1909), pp. xix, 83, pls. 8, by M. Cossmann and G. Pissarro. Introduction, by E. W. Vredenburg. Price 2 Rs.
The Brachiopoda of the Namyau Beds, Northern Shan States, Burma. Vol. III, Memoir No. 2 (1917), pp. 254, pls. 21, by S. S. Buckman. Price 5 Rs. 4 As.
On some Fish-remains from the Beds of Dongargaon, Central Provinces: Vol. III, Memoir No. 3 (1908), pp. 6, pl. 1, by Dr. A. Smith Woodward. Price 1 Re.
Anthracolithic Fossils of the Shan States: Vol. III, Memoir No. 4 (1911), pp. 74, pls. 7, by Dr. C. Diener. Price 1 Re. 12 As. (*out of print*).
The Fossil Giraffidæ of India: Vol. IV, Memoir No. 1 (1911), pp. 29, pls. 5, by Dr. G. E. Pilgrim. Price 1 Re. 4 As.
The Vertebrate Fauna of the Gaj Series in the Bugti Hills and the Punjab: Vol. IV, Memoir No. 2 (1912), pp. 83, pls. 30 and map, by Dr. G. E. Pilgrim. Price 8 Rs.
Lower Gondwana Plants from the Golabgarh Pass, Kashmir: Vol. IV, Memoir No. 3 (1912), pp. 10, pls. 3, by A. C. Seward. Price 1 Re.
Mesozoic Plants from Afghanistan and Afghan-Turkistan: Vol. IV, Memoir No. 4 (1912), pp. 57, pls. 7, by A. C. Seward. Price 1 Re. 12 As.
Triassic Fauna of Kashmir: Vol. V, Memoir No. 1 (1915), pp. 133, pls. 13, by Dr. C. Diener. Price 3 Rs. 4 As.
The Anthracolithic Faunæ of Kashmir, Kanaur and Spiti: Vol. V, Memoir No. 2 (1915), pp. 135, pls. 11, by Dr. C. Diener. Price 2 Rs. 12 As.
Le Crétacé et l'Eocène du Tibet Central: Vol. V, Memoir No. 3 (1916), pp. 52, pls. 16, by Prof. Henri Douvillé. Price 4 Rs.
Supplementary Memoir on New Ordovician and Silurian fossils from the Northern Shan States: Vol. VI, Memoir No. 1 (1915), pp. 98, pls. 12, by F. R. C. Reed. Price 3 Rs.
Devonian Fossils from Chitral and the Pamirs: Vol. VI, Memoir No. 2 (1922), pp. 136, pls. 16, by F. R. C. Reed. Price 4 Rs.
Ordovician and Silurian Fossils from Yunnan: Vol. VI, Memoir No. 3 (1917), pp. 69, pls. 8, by F. R. C. Reed. Price 2 Rs.
Upper Carboniferous Fossils from Chitral and the Pamirs: Vol. VI Memoir No. 4 (1925), pp. 134, pls. 10, by F. R. C. Reed. Price 9 Rs. 13 As.

Indian Gondwana Plants. A Revision: Vol. VII, Memoir No. 1 (1920), pp. 41, pls. 7, by A. C. Seward and B. Sahni. Price 1 Re. 12 As.

The Lamellibranchiata of the Eocene of Burma: Vol. VII, Memoir No. 2 (1923), pp. 24, pls. 7, by Dr. G. de P. Cotter. Price 3 Rs. 10 As.

A Review of the Genus Gisortia with descriptions of several species: Vol. VII, Memoir No. 3 (1926), pp. 78, pls. 32, by E. Vredenburg. Price 10 Rs. 5 As.

An incomplete skull of Dinotherium with notes on the Indian forms: Vol. VII, Memoir No. 4 (1924), pp. 13, pls. 3, by R. W. Palmer. Price 1 Re. 2 As.

Contributions to the Palæontology of Assam: Vol. VIII, Memoir No. 1 (1923), pp. 74, pls. 4, by Erich Spengler. Price 5 Rs.

The Anthracotheriidæ of the Dera Bugti deposits in Baluchistan: Vol. VIII, Memoir No. 2 (1924), pp. 59, pls. 7, by C. Forter Cooper. Price 4 Rs.

The Perissodactyla of the Eocene of Burma: Vol. VIII, Memoir No. 3 (1925), pp. 28, pls. 2, by Dr. G. E. Pilgrim. Price 1 Re. 9 As.

The Fossil Suidæ in India: Vol. VIII, Memoir No. 4 (1926), pp. 65, pls. 20, by Dr. G. E. Pilgrim. Price 11 Rs. 12 As.

On the Blake Collection of Ammonites from Kachh: Vol. IX, Memoir No. 1 (1924), pp. 29, by L. F. Spath. Price 12 As.

Revision of the Jurassic Cephalopod Fauna of Kachh (Cutch): Vol. IX, Memoir No. 2. Part I (1927), pp. 71, pls. 1—7, price 4 Rs. 12 As.; Part II (1928), pp. 73—161, pls. 8—19, price 7 Rs. 14 As.; Part III (1928), pp. 163—278, pls. 20—47, price 15 Rs. 4 As.; Part IV (1931), pp. 279—550, pls. 48—102, price 34 Rs. 12 As.; Part V (1931), pp. 551—658, pls. 103—121, price 12 Rs. 14 As.; by L. F. Spath.

Palæozoic and Mesozoic Fossils from Yunnan: Vol. X, Memoir No. 1 (1927), pp. 291, pls. 20, by F. R. C. Reed. Price 20 Rs. 9 As.

The Mollusca of the Ranikot Series (together with some species from the Cardita Beaumonti Beds): Vol. X, Memoir 2 (1927), pp. 31, pls. 4, by M. Cossmann and G. Pissarro, revised by the late Mr. E. Vredenburg, with an introduction and editorial notes by Dr. G. de P. Cotter. Price 2 Rs. 6 As.

Les Couches à Cardita Beaumonti: Vol. X, Memoir No. 3. Les Couches à Cardita Beaumonti dans le Bélouchistan: Fasc. I (1928), pp. 25, pls. 4, price 2 Rs. 12 As.; Les Couches à Cardita Beaumonti dans le Sind: Fasc. II (1929), pp. 27—73, pls. 5—11, price 4 Rs. 8 As.; by Prof. Henri Douvillé.

A Supplement to the Mollusca of the Ranikot Series: Vol. X, Memoir No. 4 (1928), pp. 75, pls. 9, by the late E. W. Vredenburg, edited with notes by Dr. G. de P. Cotter. Price 6 Rs. 12 As.

Revisions of Indian Fossil Plants: Vol. XI. Coniferales (a. Impressions and Incrustations): Part I (1928), pp. 1—49, pls. 1—6, price 3 Rs. 12 As.; Coniferales (b. Petrifactions): Part II (1931), pp. 51—124, pls. 7—15, price 7 Rs. 6 As.; by Prof. B. Sahni.

The Fauna of the Agglomeratic Slate Series of Kashmir: Vol. XII (1928), pp. 42, pls. 8, by the late H. S. Bion, with an Introductory Chapter by C. S. Middlemiss. Price 6 Rs. 8 As.

The Artiodactyla of the Eocene of Burma: Vol. XIII (1928), pp. 39, pls. 4, by Dr. G. E. Pilgrim. Price 3 Rs. 12 As.

A Sivapithecus Palate and other Primate Fossils from India: Vol. XIV (1927), pp. 24, pl. 1, by Dr. G. E. Pilgrim. Price 1 Re. 8 As.

The Fossil Fauna of the Samana Range and some Neighbouring Areas: Vol. XV. An Introductory Note: Part I (1930), pp. 15, pls. 1-4, price 1 Re. 4 As.; by Lt.-Col. L. M. Davies, R.A., F.G.S. The Albian Echinoidea: Part II (1930), pp. 17-23, pl. 4a, price 12 As.; by Ethel D. Currie, B.Sc., Ph.D., F.G.S. The Brachiopoda: Part III (1930), pp. 25-37, pls. 5-6, price 1 Re. 4 As.; by Helen Marguerite Muir-Wood, M.Sc., F.G.S. Lower Albian Gastropoda and Lamellibranchia: Part IV (1930), pp. 39-49, pl. 7, price 14 As.; by L. R. Cox, M.A., F.G.S. The Lower Cretaceous Ammonoidea; with Notes on Albian Cephalopoda from Hazara: Part V (1930), pp. 51-66, pls. 8-9, price 1 Re. 6 As.; by L. F. Spath, D.Sc., F.G.S. The Palæocene Foraminifera: Part VI (1930), pp. 67-79, pl. 10, price 14 As.; by Lt.-Col. L. M. Davies, R.A., F.G.S. The Lower Eocene Corals: Part VII (1930), pp. 81-128, pls. 11-16, price 3 Rs. 14 As.; by J. W. Gregory, LL.D., D.Sc., F.R.S. The Mollusca of the Hangu Shales: Part VIII (1930), pp. 129-222, pls. 17-22, price 4 Rs. 14 As.; by L. R. Cox, M.A., F.G.S.

Upper Carboniferous Fossils from Tibet: Vol. XVI (1930), pp. 37, pls. 4, by F. R. C. Reed. Price 3 Rs. 6 As.

New Fossils from the Productus Limestones of the Salt Range, with notes on other species. Vol. XVII (1931), pp. 56, pls. 8, by F. R. C. Reed. Price 5 Rs. 6 As.

The Fossil Carnivora of India: Vol. XVIII (*in the press*), by Dr. G. E. Pilgrim.

Upper Carboniferous Fossils from Afghanistan: Vol. XIX (1931), pp. 39, pls. 4, by F. R. C. Reed. Price 3 Rs. 10 As.

Index to the Genera and Species described in the Palæontologia Indica, up to the year 1891. Price 1 rupee.

RECORDS OF THE GEOLOGICAL SURVEY OF INDIA.

VOL. I, 1868.

Part 1 (out of print).—Annual report for 1867. Coal-seams of Tawa valley. Coal in Garrow Hills. Copper in Bundelkhund. Meteorites.

Part 2 (out of print).—Coal-seams of neighbourhood of Chanda. Coal near Nagpur. Geological notes on Surat collectorate. Cephalopodous fauna of South Indian cretaceous deposits. Lead in Raipur district. Coal in Eastern Hemisphere. Meteorites.

Part 3 (out of print).—Gastropodous fauna of South Indian cretaceous deposits. Notes on route from Poona to Nagpur *via* Ahmednuggur, Jalna, Loonar, Yeotmahal, Mangali and Hingunghat. Agate-flake in pliocene (?) deposits of Upper Godavery. Boundary of Vindhyan series in Rajputana. Meteorites.

VOL. II, 1869.

Part 1 (out of print).—Valley of Poorna river, West Berar. Kuddapah and Kurnool formations. Geological sketch of Shillong plateau. Gold in Singhbhum, etc. Wells at Hazareebagh. Meteorites.

Part 2 (out of print).—Annual report for 1868. Pangshura tecta and other species of Chelonia from newer tertiary deposits of Nerbudda valley. Metamorphic rocks of Bengal.

Part 3 (out of print).—Geology of Kutch, Western India. Geology and physical geography of Nicobar Islands.

Part 4 (out of print).—Beds containing silicified wood in Eastern Prome, British Burma. Mineralogical statistics of Kumaon division. Coal-field near Chanda. Lead in Raipur district. Meteorites.

VOL. III, 1870.

Part 1 (out of print).—Annual report for 1869. Geology of neighbourhood of Madras. Alluvial deposits of Irrawadi, contracted with those of Ganges.

Part 2 (out of print).—Geology of Gwalior and vicinity. Slates at Chitchi, Kumaon. Lead vein near Chicholi, Raipur district. Wardha river coal fields, Berar and Central Provinces. Coal at Korba in Bilaspur district.

Part 3 (out of print).—Mohpani coal-field. Lead ore at Slimanabad, Jabalpur district. Coal east of Chhattisgarh between Bilaspur and Ranchi. Petroleum in Burma. Petroleum locality of Sudkal, near Futtijung, west of Rawalpindi. Argentiferous galena and copper in Manbhum. Assays of iron ores.

Part 4 (out of print).—Geology of Mount Tilla, Punjab. Copper deposits of Dalbhum and Singhbhum: 1.—Copper mines of Singhbhum: 2.—Copper of Dalbhum and Singhbhum. Meteorites.

VOL. IV, 1871.

Part 1 (out of print).—Annual report for 1870. Alleged discovery of coal near Gooty, and of indications of coal in Cuddapah district. Mineral statistics of Kumaon division.

Part 2 (out of print).—Axial group in Western Prome. Geological structure of Southern Konkan. Supposed occurrence of native antimony in the Straits Settlements. Deposit in boilers of steam-engines at Raniganj. Plant-bearing sandstones of Godavari valley, on southern extensions of Kamthi group to neighbourhood of Ellore and Rajmandri, and on possible occurrence of coal in same direction.

Part 3 (out of print).—Borings for coal in Godavari valley near Dumaguden and Bhadrachalam Narbada coal-basin. Geology of Central Provinces. Plant-bearing sand stones of Godavari valley.

Part 4 (out of print).—Ammonite fauna of Kutch. Raipur and Hengir (Gangpur) Coal-field. Sandstones in neighbourhood of first barrier on Godavari, and in country between Godavari and Ellore.

VOL. V, 1872.

Part 1 (out of print).—Annual report for 1871. Relations of rocks near Murree (Mari), Punjab. Mineralogical notes on gneiss of South Mirzapur and adjoining country. Sandstones in neighbourhood of first barrier on Godavari, and in country between Godavari and Ellore.

Part 2 (out of print).—Coasts of Baluchistan and Persia from Karachi to head of Persian Gulf, and some of Gulf Islands. Parts of Kummummet and Hanamconda districts in Nizam's Dominions. Geology of Orissa. New coal-field in south-eastern Hyderabad (Deccan) territory.

Part 3 (out of print).—Maskat and Massandim on east of Arabia. Example of local jointing. Axial group of Western Prome. Geology of Bombay Presidency.

Part 4 (out of print).—Coal in northern region of Satpura basin. Evidence afforded by raised oyster banks on coasts of India, in estimating amount of elevation indicated thereby. Possible field of coal-measures in Godavari district, Madras Presidency. Lameta or intra-trappean formation of Central India. Petroleum localities in Pegu. Supposed eozoonal limestone of Yellam Bile.

VOL. VI, 1873.

Part 1.—Annual report for 1872. Geology of North-West Provinces.

Part 2 (out of print).—Bisrampur coal-field. Mineralogical notes on gneiss of south Mirzapur and adjoining country.

Part 3 (out of print.)—Celt in ossiferous deposits of Narbada valley (Pliocene of Falconer) on age of deposits, and on associated shells. Barakars (coal-measures) in Beddadanole field, Godavari district. Geology of parts of Upper Punjab. Coal in India. Salt-springs of Pegu.

Part 4 (out of print).—Iron deposits of Chanda (Central Provinces). Barren Islands and Narkondam. Metalliferous resources of British Burma.

VOL. VII, 1874.

Part 1 (out of print).—Annual report for 1873. Hill ranges between Indus valley in Ladak and Shah-i-Dula on frontier of Yarkand territory. Iron ores of Kumaon. Raw materials for iron-smelting in Raniganj field. Elastic sandstone, or so-called Itacolumyte. Geological notes on part of Northern Hazaribagh.

Part 2 (out of print).—Geological notes on route traversed by Yarkand Embassy from Shah-i Dula to Yarkand and Kashgar. Jade in Karakash valley, Turkistan. Notes from Eastern Himalaya. Petroleum in Assam. Coal in Garo Hills. Copper in Narbada valley. Potash-salt from East India. Geology of neighbourhood of Mari hill station in Punjab.

Part 3 (out of print).—Geological observations made on a visit to Chadderkul, Thian Shan range. Former extension of glaciers within Kangra district. Building and ornamental stones of India. Materials for iron manufacture in Raniganj coal-field. Manganese-ore in Wardha coal-field.

Part 4 (out of print).—Auriferous rocks of Dhambal hills, Dharwar district. Antiquity of human race in India. Coal recently discovered in the country of Luni Pathans, south-east corner of Afghanistan. Progress of geological investigation in Godavari district, Madras Presidency. Subsidiary materials for artificial fuel.

VOL. VIII, 1875.

Part 1 (out of print).—Annual report for 1874. The Altum-Artush considered from geological point of view. Evidences of 'ground-ice' in tropical India, during Talchir period. Trials of Raniganj fire-bricks.

Part 2 (out of print).—Gold-fields of south-east Wynaad, Madras Presidency. Geological notes on Khareean hills in Upper Punjab. Water-bearing strata of Surat district. Geology of Scindia's territories.

Part 3 (out of print).—Shahpur coal-field, with notice of coal explorations in Narbada regions. Coal recently found near Mollong, Khasia Hills.

Part 4 (out of print).—Geology of Nepal. Raigarh and Hingir coal-fields.

VOL. IX, 1876.

Part 1 (out of print).—Annual report for 1875. Geology of Sind.

Part 2 (out of print).—Retirement of Dr. Oldham. Age of some fossil floras of India. Cranium of Stegodon Ganesa, with notes on sub-genus and allied forms. Sub-Himalayan series in Jamu (Jammoo) Hills.

Part 3 (out of print).—Fossil floras in India, Geological age of certain groups comprised in Gondwana series of India, and on evidence they afford of distinct zoological and botanical terrestrial regions in ancient epochs. Relations of fossiliferous strata at Maleri and Kota, near Sironcha, C. P. Fossil mammalian faunæ of India and Burma.

Part 4 (out of print).—Fossil floras in India. Osteology of Merycopotamus dissimilis. Addenda and Corrigenda to paper on tertiary mammalia. Plesiosaurus in India. Geology of Pir Panjal and neighbouring districts.

MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

VOLUME LXI.

THE GEOLOGY AND COAL RESOURCES OF THE RANIGANJ COALFIELD. BY E. R. GEE, M.A. (CANTAB.), F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plates 1 to 20.)

Published by order of the Government of India.

CALCUTTA: GOVERNMENT OF INDIA
CENTRAL PUBLICATION BRANCH
1932

CONTENTS.

LIST OF PLATES.

NOTE.—The positions of the bore-holes, sections of which are included in Plates 16 to 18, are demarcated both on the enclosed 1 inch to 1 mile geological map (Plates 19 and 20), and on the 4 inches to 1 mile geological sheets.

TEXT FIGURES.

TEXT TABLES.

MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

THE GEOLOGY AND COAL RESOURCES OF THE RANIGANJ COALFIELD. BY E. R. GEE, M.A. (CANTAB.), F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plates 1 to 20.)

PART I.

CHAPTER I.

INTRODUCTION.

The Raniganj coalfield, though now standing second on the list of coal-producing regions of India, can, at least, claim the distinction of being the birthplace of the Indian coal industry. Up to the year 1905 it retained the premier position among Indian coalfields as regards output; since that date, however, it has been superseded by the Jharia field.

The earliest official reference in connection with the exploitation of coal in India, is contained in a memorial, dated 11th August, 1774, which was presented to Government by Messrs. S. G. Heatly and J. Sumner, of the Bengal Civil Service.[1] This memorial refers to the discovery of 'certain coal mines in Pachete and Bheerbhoom,' within the Raniganj field, and includes 'proposals for working coal mines and selling coal in Bengal.' Mining was apparently commenced in the following year at Aitura (Aytooreah), Chinakuri and Damulia.

Earliest reference to the mining of coal in India.

[1] *Journ. Asiat. Soc. Beng.*, XI, Pt. I, pp. 813-814, (1842).

Two years later, in 1777, the iron-ore deposits of the Raniganj coalfield were brought to the notice of Government in a proposal by Messrs. Motte and Farquhar,[1] 'to bore cannon and to cast shot and shell in the pergunnah of Jerriah.' These early pioneers stated:—

Earliest reference to the iron-ore deposits of the Raniganj field.

'We are of opinion, that the pergunnah called Jerriah, lying between the rivers Dummooda and Burraker in the province of Pachete, is the fittest situation for the iron works. The river Dummooda is navigable as high as that place. It abounds with iron-ores, and has the singular advantage of being contiguous to the coal mines of which Sumner and Heatly have a grant.'

From old topographical maps, prepared by J. Rennell in 1779, Dr. Fox observes that the pergunnah of Jerriah is included in the western part of the present Raniganj field[2].

The earliest published account referring to the geology of the Raniganj coalfield, appears to be a paper by Mr. Rupert Jones who, in 1815, opened mines at Raniganj. Following several unfavourable reports on the quality and value of Indian coals, Mr. Jones had been brought from England at the instigation of the Marquis of Hastings to carry out an examination of the Bengal coalfields. His report was on the whole favourable, and showed that Bengal coal might very well be used for many of the purposes for which English coal was being imported. His paper entitled 'Description of the North-West Coal District, stretching along the river Damoodah from the neighbourhood of Jerria or Juriargerh, to below Sanampur; in the Pergunnah of Sheargerh, forming a line of about 65 miles,'[3] was apparently written in 1817, but was not published until 1829. Dr. T. Oldham suggests[4]:—

Mr. Rupert Jones, 1817.

'That the name "Jerria" was used by Mr. Jones, not as indicating the town of that name, but rather the property of "raj" which was next adjoining the country near the Barakar river, known to contain coal.'

The name apparently refers to the same tract of country mentioned previously in the proposal submitted to Government by Motte and Farquhar in 1777. The principal portion of the paper is confined to a description of the Raniganj seam, and the sinking of the shaft for the Raniganj mine, where, in 1815 or 1816, Mr. Jones commenced working coal on his own account.

[1] *Journ. Asiat. Soc. Beng.*, XI, Pt. I, p. 822, (1842).
[2] *Trans. Min. Geol. Inst. Ind.*, XXIV, p. 98, (1929).
[3] *Journ. Asiat. Soc. Beng.*, (*Asiatic Researches*), XVIII, p. 163, (1829).
[4] *Mem. Geol. Surv. Ind.*, V, p. 333, (1866).

Mr. Jones also speculates on the possibilities of coal beneath the alluvium to the east. His knowledge of the geology of the coalfield appeared, however, to have been very limited, and his report could not be regarded as a reliable geological treatise.

References to the geology of the field were made by various writers in the years which followed. These include a short notice of 'Geological Observations made on a journey from Calcutta to Ghazipur' by the Reverend R. Everest.[1] He gives a striking description of the burnt outcrop of the Raniganj seam simulating it to an outburst or eruption, in some ways like a volcanic eruption. Other geological details noted by Everest include many inaccurate statements, showing that his knowledge of the field was also limited.

Reverend R. Everest, 1831.

The Raniganj coalfield is again briefly referred to by De la Beche, in his Geological Manual, 1833.[2]

De la Beche, 1833.

Dr. Forbes Royle, in his introduction to the 'Illustrations of the Botany, etc., of the Himalayan Mountains,'[3] published in 1839, briefly mentions the coal formation of Chinnakooree (Chinakuri), and gives a section of the beds from Chinakuri to Pachete (Panchet) hill. Unlike many other authors, he has correctly described the rocks of Panchet hill as consisting of conglomerate and sandstone, and also puts them in a distinct series from the rest of the field.

Dr. Forbes Royle, 1839.

In 1838, the first 'Report of the Committee for investigating the coal and mineral resources of India,'[4] was published. The account of the 'Burdwan and Adjai' field, however, showed little advancement beyond the previous description given by Mr. Jones, together with certain facts regarding the Adjai area by a Mr. Erskine. Information regarding other areas where coal was known to exist within the field was given by Mr. J. Homfray of Messrs. Jessop & Co., but these data appear to have been very little appreciated by the committee. So little reliable information was available regarding the geology of the coalfield, and its reserves of coal were so lightly regarded, that, although Calcutta was, even at that time largely

Report of Coal Committee, 1838.

[1] *Gleanings of Science,* III, p. 129.
[2] 'Geological Manual' (3rd edit., 1833) p. 399.
[3] 'Illustrations of the Botany, etc., of the Himalayan Mountains,' p. 29, (1839).
[4] Report of the Committee for investigating the Coal and Mineral resources of India (1838).

supplied from it, the coalfield was regarded as second in importance to that of Sylhet. As Dr. W. T. Blanford very justly remarks in his memoir, published in 1861[1] :—

'It is singular to find that the Committee, who would seem almost systematically to have exaggerated all accounts of distant coalfields, should have so much neglected the far more valuable deposits in the neighbourhood of Calcutta; but this may be partly explained by the circumstance that one cause of their being appointed was the difficulty of carriage by the River Damuda, and the desirability of obtaining coal from some district more easy of access.'

Mr. J. Homfray, 1842.

In 1842, Mr. J. Homfray, at that time manager of Messrs. Jessop & Co.'s colliery at Narrainkuri, published the first general account of the Raniganj coalfield, entitled 'A description of the coalfield of the Damuda Valley, and the adjacent countries of Bheerbhoom and Pooroolecah, as applicable to the present date, 1842.'[2] Although adding much useful information to the previously recorded data, his comments on the geology of the field are decidedly inaccurate. Mr. Homfray published a second paper in 1847.

Dr. J. Hooker, 1855.

In Volume I, of his Himalayan Journals,[3] Dr. Hooker refers briefly to the Raniganj field. He points out the uncertainty of all determinations of the age of rocks, when based solely on the evidence of fossil plants.

Mr. D. H. Williams, 1845-1847.

During the years 1845 and 1846, the Raniganj field was first systematically mapped and reported upon. Mr. D. H. Williams, who had been attached to the Geological Survey of Great Britain, and had been engaged in an examination of the South Wales coalfields, was appointed Geological Surveyor to the Honourable East India Company, and was deputed to Bengal in 1845. His report,[4] dated 7th December, 1847, was not published till 1850, after his death. This report has been commented on in detail by Dr. Blanford[5]. Regarding the map, Blanford states (p. 8) :—

'The Geological map, which also bears the date of 1847, was published in India, together with some horizontal sections, and a vertical section of the whole of the strata contained in the field. Of the map, considering that the topographical and geological work was necessarily carried on at the same time, it is difficult to speak

[1] *Mem. Geol. Surv. Ind.*, III, Pt. I, p. 5, (1861).
[2] *Journ. Asiat. Soc. Beng.*, XI, p. 723.
[3] Hooker's 'Himalayan Journals,' I, p. 7, (1855).
[4] A Geological Report on the Damoodah valley, by D. H. Williams, Esq., late Geological Surveyor in the service of the East India Company.' Printed by order of the Court of Directors, 1850. Subsequently reprinted in Calcutta 1853.
[5] *Mem. Geol. Surv. Ind.*, III, Pt. I, (1861).

too highly. The boundaries are mostly true and well mapped; the coal seams correctly laid down.'

Regarding the report he writes:—

'It is full of type errors, especially as regards names of places. It is, moreover, by no means clearly written, and so deficient in arrangement as to be almost unintelligible to any one unacquainted with the district. But, considering the circumstances under which the Report was printed and published, these defects are scarcely chargeable to Mr. Williams. On the other hand, the statements are, for the most part, accurate; the various rocks are well and clearly described and, in general, the relations of the different beds to each other are correctly made out.'

Again quoting from Blanford (pp. 20-22), the most important points established by Williams included the following:—

'*1st.*—He clearly showed a great succession of beds, the whole of which, with one exception (his "upper measures"), he interpreted correctly. From his vertical section we may take the following as an abstract:—

Upper Measures.	Feet	
Beds of Singharun Valley . . . . . . about .	1,500	
Beds of Raniganj, Narrainkuri, and Rogonath chuk . .	500	2,000
Middle Measures.		
"Measures containing red marl unexplored"	800	
Ditto ditto Marulia and Bagalgoria coal . .	1,600	
Ditto ditto Salunchi (Chinakuri now) coal . .	600	
Ditto ditto Chinakuri coal and thence to top of the carbonaceous shales, containing ironstone, including all the beds seen North-west of Chinakuri, the Nudia coal, etc.	2,300	5,300
Carbonaceous shales and ironstones		1,000
Lower measures	2,500	
Conglomerates and greenish-grey shales (Talchir) . .	700	3,200
Total .		11,500

'It will be seen that, although some difference in the exact figures may occur, the above has, in the main, been perfectly confirmed by the results of the present survey—always with the exception of the upper measures of Mr. Williams, which will be shown to be equivalent to the beds in the neighbourhood of Chinakuri forming the central parts of his middle measures.'

'*2nd.*—The great faults cutting off and bounding the coal-bearing rocks on the South and West were correctly determined and mapped, and the general geological structure of the field and its Southerly dip clearly shown by the sections.'

'*3rd.*—The various coal seams were, in many cases first discovered, in all cases first mapped. Several additional seams have, however, been discovered since Mr. William's survey.'

'*4th.*—Many of the errors of Mr. Homfray and of the Coal Committee were exposed and corrected.

'*5th.*—The occurrence of the great band of carbonaceous shales, containing ironstones, and their position in the series, was determined. The "greenish-grey shales" of the Talchir group were noticed, as also their absence in the North-eastern portion of the field.'

'But, on the other hand, several important geological facts were left undetermined. The greenish-grey shales and conglomerates (now recognised as belonging to the Talchir group) and the beds containing red marls (here described as the Panchet group),were observed, but were not separated from the other rocks, sufficient importance not having been attached to the evidence of their unconformity with the true Damuda series. The separation caused in the general series by the band of ironstone shales was not given sufficient prominence, and the beds of Raniganj and of the Singharun Valley were entirely misplaced. Mr. Williams was also led by his English experience erroneously to anticipate that faults would be found co-existent with trap dykes, and that the coal seams would be found equally co-extensive with the beds accompanying them. The map is also erroneous in representing Pachet (Pachete), Beharinath, Garangi, and Telinda or Madjia Hills, as gneiss. The boundaries generally required greater exactitude. But such detailed errors of mapping are more than excused by the difficulties under which he laboured. No topographical map of the country existed; that published was laid down during the progress of Mr. William's survey, and the geological work was frequently in advance of the topographical, and had to be put on paper subsequently.'

'As regards the geological relations of the beds of the Damuda field with those in Europe, Mr. Williams appears never to have doubted that all the Indian coal-bearing strata belonged to the same age as the carboniferous formation of European geologists.'

Survey by Blanford and Willson, 1858-1860.

In the years 1858-1860, seven years after the formation of the Geological Survey of India under the superintendence of Mr. Thomas Oldham, the Raniganj field was geologically mapped on a scale of one inch to one mile by Messrs. W. T. Blanford and W. L. Willson. During the latter part of 1860, the map, together with a detailed report, written by Dr. Blanford,[1] was prepared. It would be difficult to speak too highly of this geological map and memoir. Of the former, the boundaries both of the limits of the coalfield, and of the groups of his classification, are extremely accurate, and for many years this geological map has served as a useful guide to colliery development. In 1905, it formed a very satisfactory basis to the geological map compiled by Mr. G. A. Stonier,[2] late Chief Inspector of Mines, in which was

Map by Mr. G. A. Stonier, 1905.

[1] *Mem. Geol. Surv. Ind.*, III, Pt. I, (1861).
[2] Geological Map of the Raniganj Coalfield, by G. A. Stonier (1905).

plotted additional information regarding the coal seams, brought to light as a result of the expansion of the industry. Blanford's report is also deserving of the highest commendation. The classification which he adopted has been upheld in all subsequent surveys. In his description of the lithology of the various groups of strata he was extremely lucid and accurate, and were it not for the fact that his report is now out of print much of the general stratigraphy included in this memoir, would be superfluous. As a source of information regarding the early history of the Raniganj field, and of the pioneer work of colliery development, his report has been most valuable, and will be referred to a number of times in this description of the coalfield.

Blanford's report, 1860.

With the development of a number of new collieries, and the discovery of new seams, it was felt that a geological map of the Raniganj field, on a scale larger than one inch to the mile, was required. As a result, during the years 1908-1910, a third geological survey was carried out under the direction of a committee of the Mining and Geological Institute of India. The topographical map was on a scale of 4 inches to one mile, enlarged from the original used by the late Dr. W. T. Blanford. The results of this survey were also published on a one-inch scale. The demarcation of the geological boundaries was carried out by Mr. H. Walker, of the Geological Survey of India, while the revision of the data derived from colliery development was in the hands of Mr. R. R. Simpson, of the Department of Mines. In a paper read to the Mining and Geological Institute of India, and published in 1913,[1] Mr. Walker gives a brief description of the geology of the Raniganj field. This paper refers principally, however, to the correlation of certain of the coal seams of the coalfield. A summary of the geology of the Raniganj coalfield with particular reference to the coal seams, is also given in the memoir on 'The Coalfields of India,' by Mr. Simpson, also published in 1913.[2] The geological sheets resulting from this survey, have been of very considerable value in the development of the coalfield during the past 20 years.

Re-survey and report by Messrs. Walker and Simpson, 1908-1910.

[1] *Trans. Min. and Geol. Inst. Ind.*, VII, Pt. 3, p. 226, (1913).

[2] *Mem. Geol. Surv. Ind.*, XLI, Pt. 1. (1913).

Mr. Treharne Rees, Coal Committee, 1920.

In 1919, Mr. Treharne Rees, a mining engineer engaged by the Government of India for the purpose, visited the coalfields of Raniganj and Jharia, and in August of that year submitted a report on the best means of securing greater economy in the production and consumption of coal.[1] The Coalfields Committee was constituted in January, 1920, for the purpose of considering the recommendations made in Mr. Rees' report. The principal recommendations of their majority report included :—

1. The appointment of a Controlling Authority with legal powers designed to ensure conservation and economic extraction.
2. That sand-stowing should be made compulsory within certain limits.
3. That the Land Acquisition Act should be amended to provide facilities for the acquisition of :—
   (a) surface rights for colliery purposes,
   (b) sand and other materials suitable for stowing, and
   (c) land required for the conveyance of sand.

These recommendations were, however, not put into force.

Indian Coal Committee, 1925.

In 1925, another Coal Committee was appointed to report on the measures which might be taken to stimulate the export of suitable coal from Calcutta to Indian and foreign ports, and whether effective measures could be taken for pooling and grading Indian coal for export and for bunkering. As a result of the recommendations of this committee,[2] the Indian Coal Grading Board was established.

Mr. R. R. Simpson, 1929.

A more recent publication, the 'Indian Mines Manual' by Mr. R. R. Simpson, Chief Inspector of Mines in India,[3] includes a summary of the geology and mineral resources of India (written by Dr. C. S. Fox).

The maps used by Messrs. Walker and Simpson in 1908-1910, although of a sufficiently large scale were lacking in topographical details so that it was impossible to demarcate with certainty the exact position of outcrops, faults, dykes, etc. This, together with the marked increase in the number of collieries during recent years, resulting in much additional information regarding the coal seams and the detailed structure of the field, pointed to the fact that in order

[1] Report of the Coalfields Committee (1920).
[2] Report of the Indian Coal Committee (1925).
[3] The Indian Mines Manual, pub. Calcutta 1929.

to arrive at a reliable estimate of the coal reserves of the Raniganj field, an accurate large-scale geological map was indispensable. Accordingly, during the seasons 1923-1925, as a result of representations by the Director, Geological Survey of India, new topographical maps,[1] on a scale of 4 inches to one mile, were prepared by the Survey of India. Using these recently constructed maps, the present geological survey of the Raniganj field was commenced during the field-season 1925-26. The party, under the superintendence of Dr. C. S. Fox included, the late Rao Bahadur S. Sethu Rama Rau, Mr. A. K. Banerji and myself. In December, 1926, Mr. J. B. Auden joined the coalfields party and was again associated with the Raniganj survey during the first half of the following season. By the end of the field-season 1927-28, the geological mapping of the field was complete. The extreme western part of the coalfield and the area to the south of the Damodar river, including Sheets 1, 2, 3, 5 (the southern portion), 6, 9 (the southern portion), 10, 14 (the southern portion) 15, and 20, was surveyed by Rao Bahadur Sethu Rama Rau. He also mapped the south-eastern corner of the field included in Sheet 24. Mr. Banerji examined Sheet 4, and continued south-eastwards into the northern part of Sheet 5. In collaboration with myself Sheet 9 was surveyed. Mr. Banerji later proceeded to the eastern end of the field mapping Sheets 22, 23 and 25. Mr. Auden assisted in the mapping of Sheet 4, and later proceeded to the north-eastern corner of the coalfield, completing the survey of Sheets 16, 17 and 21. During the greater part of the seasons 1925-26 and 1926-27, and the first half of the season 1927-28, I was occupied in the mapping of Sheets 7, 8, 9 (northern portion), 11, 12, 13, 14 (the northern portion), 18 and 19. These areas, which I had examined in detail, comprised the greater portion of the coalfield which is now being exploited, to the east of the Barakar and north of the Damodar rivers. With the principal object of arriving at a complete correlation of the coal seams of the Raniganj coalfield, I was deputed, during the early part of the field-season 1928-29, to examine those portions of the field to the west of the Barakar and to the south of the Damodar rivers, which areas I had previously not visited. The eastern end of the coalfield around Durgapur and to the north was also examined.

Geological re-survey, 1925-1928.

[1] Survey of India Calcutta. Raniganj Coalfield Survey, 1923-25. 1 mile.

In writing this memoir, I have constantly referred to the reports of my above-mentioned colleagues, in regard to the areas which they had mapped in detail. In some cases I have quoted them *verbatim*, in other instances, where this has not been possible, I have endeavoured to incorporate their views on all the more important issues which came under their consideration.

Present memoir.

The present geological re-survey of the Raniganj field has been primarily an economic one, aiming principally at a detailed description and correlation of the coal seams, the geological structure of the coal-bearing strata, and the extent to which the coal seams in particular have been affected by the numerous intrusions which intersect them. These various lines of investigation all lead up to the main question of the available reserves of the different grades of coal, the ultimate object of this survey and one of the principal themes of this memoir.

The 4 inches to one mile topographical maps provided for this re-survey were found to be very accurate, and offered a reliable basis for detailed geological mapping. The one inch to the mile map (Plates 19 and 20) has been compiled from these 4-inch survey sheets. To those who are closely acquainted with the popular nomenclature of the various towns, villages, etc., of the coalfield, it will be noticed that certain modifications have been adopted in this recent survey. Doubtless, however, any changes which have been introduced in the orthography of these sheets have received the careful consideration of the Trigonometrical Survey of India, and it can be safely assumed that the method of spelling now used is the correct one. This type of orthography has been adhered to in this memoir, though in cases where the spelling is very different from that in local use, the latter has been added in brackets.

New topographical maps, nomenclature, etc.

In the western half of the coalfield, the outcrops of the coal-bearing strata are, on the whole, fairly good; but to the east, particularly in the extreme eastern part of the field, alluvium and laterite form a superficial covering to these beds. Within the alluvial areas that have already proved to contain seams of coal, the thickness of these superficial beds normally varies up to about 40 feet, but it is certainly much greater in the unexploited portions of the field to the south-east. In calculating the position of the outcrops of the

Coal outcrops beneath alluvium.

coal seams on the evidence of bore-hole or shaft sections to the dip, and in the absence of incline workings, for the purpose of demarcating such outcrops on the geological maps, 40 feet of alluvial cover has therefore been assumed. If, as is probably the case in many places adjoining the laterite, the alluvium is considerably less than 40 feet thick, any incline or bore-hole sunk on the position of the outcrop of a seam as shown on the map, will penetrate the coal seam a short distance to the dip of its actual outcrop below the alluvium; that is to say, the Gondwana strata immediately above the coal seam will first of all be met with beneath the alluvium. There is, however, no possibility of the seam being missed, provided that the excavation is continued to a point 40 feet below the indicated outcrop. Were such a thickness of superficial alluvium not allowed for, in indicating the seams on the geological map, similar explorations might result in the coal seam being missed altogether, strata a short distance beneath the seam being met with beneath the alluvial covering. In allowing 40 feet, therefore, one is probably erring on the side of safety.

Publication of the geological maps.

Of the twenty-five 4-inch geologically-coloured sheets constituting the Raniganj coalfield, all except Nos. 15, 20, 24 and 25, have been published, and are now available to the public. Regarding the four sheets above-mentioned, Nos. 15 and 20 comprise only very narrow tracts covered by the Archæans and alluvium which adjoin the southern boundary of the field, whilst Nos. 24 and 25 in the extreme east and south-east of the coalfield, are not likely, for many years to come, to be of interest to those concerned in colliery development. It was therefore felt that the expenditure which would be incurred in printing these four sheets would not be justified. Reduced to the one-inch scale, they are, however, included in the geological map which accompanies this memoir.

Acknowledgments.

It is quite obvious to all who are acquainted with the Raniganj coalfield, that, without the information derived from colliery and bore-hole records, it would have been impossible to have followed the trend of the various coal-seams and associated intrusions, across a large part of the field. Every colliery which was working at the time of the survey was visited by one or other member of the party and, whenever possible, information regarding old closed workings was solicited. In the great majority of cases all possible help was given by the colliery

authorities and I can but express the gratitude of those engaged in this survey, to all these gentlemen, who, in supplying us with this information, have materially assisted in the production of the 4-inch maps, to which this memoir refers. In particular I would like to mention the names of Messrs. D. M. Archibald, C. E. Ashcroft, R. Barnard, W. H. Bates, F. L. Cork, A. T. Creet, W. G. Goldsworthy, P. S. Keelan, F. B. Kerridge, H. K. Nag, W. B. Penman, T. Samson, H. M. Tarlton, J. B. Wardlaw, W. Weir and also Mr. C. S. Whitworth. To the latter I am indebted for the greater number of the analyses included in Part III.

In addition, I wish to record my appreciation to the directors of the various companies interested in the Raniganj field, for their permission to include in this memoir the details of a number of bore-hole and shaft sections. Without this permission it would have been impossible to have given so detailed a treatise on the correlation of the coal seams.

Finally, I must express my indebtedness to Dr. C. S. Fox, Superintendent, Geological Survey of India, for the keen interest which he has maintained throughout this survey, and for the valuable advice and criticism which he has so generously given.

CHAPTER II.

PHYSICAL CONSIDERATIONS.

The Raniganj coalfield constitutes the most easterly of the chain of coal-bearing regions, which roughly follow the Damodar valley, within the provinces of Bengal and Bihar & Orissa. The major portion of the field lies to the east of the Barakar river, in the western part of the province of Bengal, though smaller areas to the west of the Barakar, south of the Damodar, and north of the Adjai rivers, encroach into Bihar & Orissa. The Damodar river traverses the southern half of the coalfield.

Location.

Regarding the area of Gondwana strata east of the Barakar river, the portion to the north of the Damodar lies mainly within the district of Burdwan, and includes the Ramnagar, Dishergarh, Salanpur, Asansol, Gourangdi, Churulia, Charanpur, Kalipahari, Shibpur, Raniganj, Tapasi, Kenda, Purushottampur, Ukhra and Kajora colliery areas; whilst the relatively small strip of coal-bearing rocks that crop out to the north of the Adjai river in the north-eastern part of the coalfield, is included in the adjoining districts of Santal Parganas (Bihar) and Birbhum (Bengal). Within this Trans-Adjai portion of the field are the colliery districts of Pariarpur (Poriarpur), Kasta, Arang, Raswan and the Hingla river. The Gondwanas to the south of the Damoda river cover portions of the two adjacent districts of Manbhum (Bihar & Orissa) and Bankura (Bengal). They include the colliery areas of Nadiha, Deilya (Deoli), Saltor and Parbeliya, together with the smaller workings of the Kalikapur tract to the west-south-west of Raniganj. In general, the middle and eastern parts of the coalfield, lying to the east of the longitude of the Barakar river, occur in the form of an irregular trapezium, with its longer axis following a general east-to-west direction. Mining is, at present, being carried out up to a distance of about 27½ miles east of the Barakar. The width of this major portion of the field, measured from north to south, varies from about 12 miles in the west to about 19 miles in the east.

East of the Barakar river.

Within the district of Manbhum, and adjoining the north-western corner of the above-mentioned tract, a narrow patch of Lower Gondwana rocks, about 4 to 5 miles in width, continues west of the Barakar river for a distance of about 11½ miles in a general west-north-westerly direction. This area comprises the coal localities of the Pusai *nala*, Shampur, Chatabar, Patlabari, Chanch and Kalemathi (Kalimati.)

West of the Barakar river.

The Gondwanas of the Raniganj field are bounded to the north, west and south by the Archæans. To the east, alluvium and laterite cover the Gondwana strata, and in the absence of deep bore-holes through these superficial sediments, the eastern limit of the coalfield is largely a matter of speculative opinion. The present *proved* limits of the field are, however, from long. 86° 36′ in the extreme west, to about long. 87° 20′ in the east.

Limits of coalfield.

The northern boundary of the coalfield is very irregular. In the extreme north-western corner, and again near the Adjai river to the north of Panuria, the lowest Gondwana rocks reach as far north as lat. 23° 51′. The southern boundary is, however, much more regular, and east of the longitude of the Barakar river, it follows a general easterly inclined south direction from the southern slopes of Panchet hill to just south of the Damodar river south of Raniganj.

Northern and southern boundaries.

The total area of the Raniganj field, calculated as far east as long. 87° 20′, and including the tract of Durgapur beds in the extreme south-east of the coalfield, is of the order of 619 square miles. Of this area, the western end of the field, to the west of the Barakar river, includes 52 square miles; the tract south of the Damodar river 99 square miles; the main portion of the field, between the Damodar and Adjai rivers and east of the Barakar river to long. 87° 20′, 424 square miles, whilst the narrow strip of coal-bearing rocks to the north of the Adjai, comprises the remaining 44 square miles.

Area of coalfield.

Within the Raniganj coalfield we pass from the monotonously dull topography of the Bengal plains towards the more variable and picturesque scenery of the adjoining Archæan tracts which constitute a large part of south-western Bengal and of Bihar & Orissa. In certain unexploited portions of the coalfield the scenery is attractive, but in

General topography.

the vicinity of the colliery areas, abandoned outcrop workings, mine headgears, large heaps of ash and waste and unpicturesque mining quarters invariably mar the beauty of the landscape to a greater or less degree.

Rivers.

The Damodar river, the sacred river of the Santals, entering across the south-west corner, and traversing the field in a general east-by-south direction, is the principal line of drainage. About 24 miles within the coal-field, the Damodar is joined by the Barakar river, flowing from the north and north-west. Linking up with the Barakar river a short distance north of its junction with the Damodar, the Kudia *nala*, with its tributary, the Pusai, drains the Pusai Shampur–Lakhdih area to the west. East of the Barakar, the drainage of the greater portion of the field flows into the Damodar river. The principal streams are the Dharma, Nonia, Singaran and Tamla on the north, and the Bisram, Machkanda and Tentularakh tributaries to the south. A relatively small area of coal-bearing rocks, including the Trans-Adjai tract to the north, and the Churulia-Nimsa area to the south, lies, however, within the drainage area of the Adjai river, which traverses the north-eastern corner of the coalfield in a general east-south-easterly direction. The low-lying portions of the Raniganj field are from 220 to 250 feet above sea-level. These areas grade gently up to the numerous low ridges of the eastern, northern and western parts of the field. The latter, conforming in many instances to the strike of the Gondwana outcrops, attain a maximum height of about 380 feet in the case of the ridge running north from Durgapur in the extreme eastern part of the field and of the Jambad and Kenda ridges; 450 feet in the case of the ridge traversing the Nimsa-Jamsol area to the south of the Adjai river; 530 feet in the Sarshatali area; 570 feet at Panuria; 550 feet to the north of Shyamdi and 589 feet in the Rangamati-Ramkanali ridge of the north-western corner of the coalfield.

Upland tracts.

Hills of the southern border.

The Nimsa-Jamsol ridge forms the watershed between the Damodar and the Adjai rivers in the north-eastern part of the field, and continues in a westerly and north-westerly direction *via* Churulia and Sarshatali up to Panuria; further west it is lost within the metamorphics. Along the southern border of the coalfield, abutting against the Archæans, are the prominent hills of Panchet (2,110

feet), Gorangi (952 feet), and Biharinath (1,481 feet), together with the small hill of Telinda south-east of Raniganj. Within the northern part of the coalfield near Shyamdi, the hillock of Muktichandi rises about 80 feet above the general level of the country. The metamorphics to the north, west, and south of the coalfield, include a much greater diversity of scenery. West of the Barakar river the Lower Gondwanas of the Shampur-Lakhdih tract are better exposed than to the east; the country is markedly undulating and grades into the more variable topography of the surrounding Archæans. The ridges—in particular those just north of Nirsa—correspond to the harder grit outcrops of the Barakar measures.

Vegetation.

The alluvial areas to the east, and the soil-capped tracts of Gondwana rocks of the middle portion of the field, are given up largely to rice cultivation, with occasional patches of sugar cane; the undulating laterite country to the north, and the areas of Lower Damuda outcrops to the west, include stretches of moorland, the limited vegetation of which dries up during the hot season; whilst the upland country of the extreme eastern part of the coalfield, to the north of Durgapur, is covered with jungle composed mainly of young sal (*Shorea robusta*). A similar type of jungle covers the Sarshatali—Gourangdi ridge of the northern part of the field, and the hills of the southern boundary to the south of the Damodar river. Patches of Palas (*Butea frondosa*) jungle, yielding small amounts of raw lac, occur occasionally.

Towns.

Asansol, the principal town of the Raniganj coalfield, has, for some years, replaced Raniganj as the headquarters of the western sub-division of the district of Burdwan, and is now one of the most important railway centres in Bengal. As recently as the year 1881, the locality was a rural tract, but with the advent of the railway and the rise of the coal industry, its population rapidly increased to 14,906 in 1901, and to 26,499 in 1921.

Raniganj, situated about two miles north of the Damodar river, has a population of 14,536 (census 1921), dependent to a large extent on the local pottery-works (Messrs. Burn & Co., Ltd.), paper mills (Messrs. Balmer Lawrie & Co., Ltd.), and collieries.

The other places of conspicuous size include *Andal* (*Ondal*), an important railway junction in the south-eastern part of the field; *Hirapur*, about 2½ miles south-west of Asansol, of growing import-

ance as the site of the blast furnaces of the Indian Iron & Steel Co., Ltd.; *Kulti*, at mile 146 on the Grand Trunk Road, the centre of the Bengal Iron Co., Ltd., and *Kumhardubhi*, the site of Messrs. Bird & Co.'s brick and engineering works, to the west of the Barakar river.

Population.

Regarding the population of the Raniganj field, the Chief Sanitary Officer, Asansol Mines Board of Health, states as follows:—

'The population of Asansol Mining Settlement (popularly known as Ranigunge Coalfields), according to the census of 1921, is 329,353. To this should be added an estimated floating population of 100,000. The average daily number of labour employed in the collieries is 33,000. The population can be classified as follows:--

Hindus	278,642
Mussalmans	27,089
Christians	3,752
Animists	19,474
Others	396'

The aboriginal tribes, Santals, Mundas, Oraons and Kols together with the Bauris, supply the greater proportion of the manual labour of the coalfield.

Climate.

The climate of the Raniganj coalfield is, on the whole, a comparatively healthy one, fever being relatively rare, except in certain low-lying tracts near the Damodar river. The annual average rainfall is about 55 to 60 inches, by far the greater part of which falls during the monsoon season. Day temperatures are high; the mean maximum temperature is below 80° in December and January, but rises to over 100° in April. As the monsoon approaches, during the month of June, this temperature falls and remains steady at about 90° until October. Night temperatures increase from 50°-55° in January; to 75°-80° in June, and remain almost unchanged until September.

Water-supply.

Within the Raniganj field, water for human consumption is obtained either from wells and rivers, or from large tanks which have been excavated in the vicinity of the villages. At a number of collieries, the requirements of the miners living in the surrounding *dhowras* are often adequately met from the water pumped from the underground workings. Wells, sunk in the sandstone strata of the

Gondwanas, usually give a fairly good supply at a moderate depth. To satisfy the requirements of the population of Raniganj, of the East Indian Railway at Andal, and of the Indian Iron & Steel Co., at Hirapur, wells have been sunk into the sandy alluvium of the northern edge of the Damodar river. The main pumping station of the Bengal Iron Co., Ltd., Kulti, is situated about $1\frac{1}{4}$ miles upstream from the East Indian Railway bridge at Barakar. A similar scheme has recently been carried out in the river to the north-west of Barakar village, in order to meet the additional present needs of the company; in this latter case, however, the well penetrated into the strata of the Middle Barakar measures. The East Indian Railway at Asansol obtains its water from large tanks located a short distance west of the station, and also from a pumping-plant situated in the Barakar river, west of Barakar station. The flooded, disused quarries of the Laikdih coal seam fulfil the requirements both of the population and of the engineering and brick works of Kumhardubhi. A scheme is now under consideration for the supply of the Asansol municipality with water pumped from the Damodar river. For the purpose of irrigation, water is drawn from the numerous tanks to be found in the vicinity of all the villages, or is raised from the various rivers and streams which intersect the coalfield.

Roads and ferries.

The Grand Trunk road traverses the Raniganj field, between miles 112 and 158 from Calcutta, in a general east-to-west direction, and crosses the Barakar river by a fine masonry bridge, located just east of Chirkunda village. This main roadway links up with a number of well-conditioned district board roads, which intersect the coalfield to the north and south. Ferries crossing the Damodar river at Raghunath Chak, south of Raniganj, and at Dishergarh, connect with the Bankura and Manbhum districts to the south, whilst another ferry near Pandaveswar, in the north-eastern part of the field, links up the Raniganj-Suri road to the north and south. During the dry season—November to May—the Adjai, Barakar and Damodar rivers can usually be crossed on foot at a number of points, though exceptional winter rains occasionally prevent this during short periods. During the monsoon, however, the Damodar river is navigable by country boats, and before the construction of the railway, which runs parallel to it along its north bank, large quantities of coal, in boats of 20 tons burden and upwards, were transported down the Damodar from the Raniganj mines to the depôt at Mahishabha in

Hooghly, and were thence transhipped and forwarded *via* the Ulberia canal and the Hooghly river to Calcutta.

Railways.

The coalfield is traversed by the East Indian Railway Main line, which follows westwards, parallel to the Grand Trunk road, as far as Sitarampur junction. Here the line divides, the Main line running north *via* Salanpur, whilst the Grand Chord line to Dhanbad continues westwards across the Barakar river and traverses the Kumhardubbi-Shampur portion of the coalfield. From Asansol, a line runs southwards across the Damodar river to link up with the Bengal-Nagpur Railway at Adra junction. From Andal, a branch line, crossing the Adjai just north of Baidyanathpur station, extends north to Suri. Within the past 25 years many new branch lines have been constructed to meet the requirements of the different portions of the coalfield, so that a network of lines and sidings, leading to the more important collieries, is now in existence.

CHAPTER III.

GEOLOGY.

General Geology.

Gondwana sediments.

The sedimentary rock formations which comprise the Raniganj coalfield excluding the recent and sub-recent alluvial and lateritic deposits all belong to the Gondwana system, and apparently at one time constituted a part of the great continent of Gondwanaland which extended over a considerable portion of the Southern Hemisphere. With the exception of the limited exposures of Supra-Panchet rocks, which are met with along the extreme southern boundary, and also, questionably, at the south-eastern end of the field, these sediments all belong to the Lower Gondwanas, ranging probably in age from late Carboniferous to Rhætic.

Metamorphic and intrusive rocks.

Outside the limits of this sedimentary succession is a complex of crystalline metamorphic and intrusive rocks. These are, in the main, assigned to the oldest Archæan system, though it has recently been suggested that some of the more basic intrusive and metamorphic types, and also certain of the more acid intrusions, which intersect the crystallines in the immediate vicinity of the Gondwanas, are of a somewhat more recent age. With these possible exceptions, the vast period of time between the Archæans and the basal Gondwanas is unrepresented within the precincts of the field.

Excluding the above-mentioned recent and sub-recent alluvial and lateritic deposits, the period subsequent to the Rhætic is now represented only by two phases of igneous activity resulting in the intrusion of the numerous mica-peridotite and doleritic dykes and sills which intersect the Lower Gondwana sediments.

General classification.

The accepted classification of the Gondwanas of Bengal and Bihar & Orissa, as recently revised by Dr. C. S. Fox,[1] is as follows :—

Upper Gondwanas.	Rajmahal series.	Basaltic lavas. Plant beds.	Lias.
	Dubrajpur beds.	Supra-Panchets.	Rhætic.
	(? unconformity).		
Lower Gondwanas.	Panchet series.		Lower Trias.
	Damudas . .	Raniganj measures.	Upper Permian.
		Ironstone Shales.	Middle Permian.
		Barakar measures.	Lower Permian.
	Talchir series		Upper Carboniferous.

[1] *Mem. Geol. Surv. Ind.*, LVI, p. 22, (1930).

Except in one or two details, this classification varies little from the one previously arrived at by Dr. G. de P. Cotter.[1] Earlier writers, however, including Dr. Cotter, have, on the evidence of fossil-plants, divided the Talchir series into two separate stages; a lower Talchir stage, including sediments of typical Talchir types, and an upper Karharbari stage, within which the lowermost coal-bearing rocks of certain of the coalfields have been incorporated.

The Karharbari stage.

As a result of recent investigations, however, Dr. Fox is of the opinion that the Karharbari stage should be grouped in a basal horizon of the Barakars, as a Karharbari flora has been found on the same horizon as a Barakar flora in the Hutar coalfield. No Karharbari stage can be recognised in the *Raniganj, Jharia*, and *Bokaro* coalfields. In so far as the Raniganj field is concerned, this view has been upheld by all who have assisted in the recent geological survey of that area. This is in agreement with the classification originally adopted by Dr. Blanford.

Gondwanas of the Raniganj coalfield.

The complete succession of the strata as represented in the Raniganj coalfield is as follows:—

Recent and Sub-Recent .	. Alluvial and lateritic deposits.	
Upper Gondwanas .	. Supra-Panchets (of Panchet hill, etc (? - Durgapur beds.)	
	(? unconformity).	
Lower Gondwanas .	Panchet series.	
	Damudas.	Raniganj measures.
		Ironstone Shales.
		Barakar measures.
	Talchir series.	
	(large unconformity).	
	(Archæans.)	

The following table (Table I) gives a summarised description of the various stages of the Gondwana sediments of the Raniganj field, together with their characteristic fossils, and their respective maximum thicknesses. The latter agree fairly well with the thicknesses given by Dr. Blanford,[2] but in the case of the Barakar and the Raniganj measures, borings put down in more recent years have enabled one to arrive at a more precise figure.

[1] *Rec. Geol. Surv. Ind.*, XLVIII, p. 23, (1917).
[2] *Mem. Geol. Surv. Ind.*, III, Pt. 1, p. 31, (1861).

TABLE I.—*Gondwana succession of the Raniganj coalfield.*

Stratigraphical division.	Description of beds.	Included fossils.	Maximum thickness in feet.
Supra-Panchets (of Panchet hill).	Coarse, red, yellow and grey sandstones and quartzose conglomerates, with bands of dark red shales.	Fragments of stems and fossil-wood.	? 1,000
Panchet series .	Coarse, yellow and grey, soft, micaceous, false-bedded sandstones, with thick red clays; khaki-green shales and sandstones at the base.	Plant remains (including several types distinct from the Damudas); *Glossopteris*, *Pecopteris*, *Schizoneura*: also reptilian and fish remains, *Estheria* (*Posidonia*).	2,000
Damudas. (c) Raniganj measures.	Mainly fine and medium-textured, grey and greenish, false-bedded, felspathic sandstones, with shales and coal seams.	Plant-remains including *Vertebraria*, *Trizygia*, *Glossopteris*, *Pecopteris*, *Schizoneura*, *Phyllotheca*, etc.	3,400
Damudas. (b) Ironstone Shales.	Black carbonaceous shales, with occasional sandy micaceous shales, and numerous bands of clay ironstone.	Plant-remains abundant, though not well-preserved; *Glossopteris*, etc.	1,200
Damudas. (a) Barakar measures.	Coarse conglomerates, with white and grey sandstones, often false-bedded; shales and coal seams of variable character.	Plant-remains including *Glossopteris*, *Gangamopteris*, *Vertebraria*, etc.	2,100
Talchir series .	Coarse sandstones, white or slightly variegated at the top, fine khaki-green and blue-green shales, with sandy shales and fine green sandstones, including undecomposed felspar; at the base is a boulder bed, including boulders up to 15 feet diameter.	Plants very rare, a few stems, seeds ?, etc.	900
		Total .	**10,600**

General structure. In general, the geological structure of the Raniganj field is of a comparatively simple type. Over the greater portion of the field the dip of the beds is in a southerly direction. The Talchirs are, therefore, exposed adjoining the northern boundary, and successively newer Gondwana horizons come in as the coalfield is traversed from north to south. Except along certain limited tracts of the north-eastern edge of the field, the boundary of the basal Gondwanas and the metamorphics is a line of natural deposition, normally unconformable and irregular, and, at a subsequent date, further complicated by faulting.

Along the southern boundary of the coalfield, to the west of the Barakar river, various horizons of the Barakar measures crop out for a considerable distance against the metamorphics, though occasional small outcrops of Talchir sediments are observed; but further east, where the area of Gondwana rocks widens considerably, the higher beds of the Gondwana succession cover large areas of the southern half of the field, and horizons ranging from the uppermost Raniganj measures up to the Supra-Panchets, are exposed adjoining the crystalline gneisses. In contrast to the northern limit of the field, this southern boundary is represented by a well-defined fault of an immense downthrow to the north, at least 9,000 feet in the vicinity of Panchet hill. In the extreme south-east of the field the continuation of this main boundary fault is largely hidden by alluvium.

The southern boundary.

CHAPTER IV.

GEOLOGY—*contd.*

The Archæans.

Beyond the limits of the Gondwanas of the Raniganj coalfield, and included as small inliers within the Talchir areas of the north-western part of the field, metamorphic rocks, belonging to the Archæan system, are well-exposed. Similar types of Archæan rocks extend over large areas of Bengal and Bihar & Orissa. These crystalline strata, previous to the deposition of the Lower Gondwana sediments, formed a somewhat irregular land-surface upon which the Talchirs, and the Barakars in the north-eastern part of the coalfield, were directly deposited. This natural line of deposition is well exposed at a number of points along the northern boundary of the coalfield; but to the south-west and south, the junction between the Gondwanas and the metamorphics is, except in the Kustabad-Kelyasota area in the vicinity of the Damodar river, undoubtedly a faulted one, following a very direct trend, though interrupted at intervals by cross-faults which step the junction to the north or south.

Distribution.

Archæan-Gondwana junction.

Since the object of this re-survey was principally the examination of the coal-bearing Damudas, time did not permit a detailed inspection of all the Archæan areas which adjoin the Raniganj field. Mr. Auden, however, examined certain tracts in greater detail and the following description, taken from his report, is representative of the exposures west of the Barakar river. He states :—

Western areas.

'The predominating type is hornblende-schist, which occurs both in the hill-masses to the north and in the flat country. The former appear to be large lenticles, almost *augen* in an extended sense. These lenticles thin out in the low-lying country where rapid alternations of hornblende-schist, quartz-hornblende-schist and quartzitic rocks occur. There are, in addition, less frequent epidote rocks and augen-gneisses. Dykes of coarse pegmatite with large crystals of quartz, orthoclase and biotite, traverse these metamorphic rocks in a general west-north-west to east-south-east direction, and also quartz-veins, with all the characters of quartz in a mineral lode (vein-brecciation, platy structure of quartz, and in-

filled vesicles). These quartz-veins often run in a north-north-east to south-south-west direction, perhaps along fault-planes.'

Eastern areas.

East of the Barakar river, the Archæans are represented by the same assemblage of rock types. To the west of the Panuria area of Lower Gondwanas, well-marked 'reefs' of white quartz run for considerable distances within these metamorphics. In the northern part of this tract, near the Adjai river, actinolite-schists and epidote rocks are included. Further east, in the Jamgram-Churulia, and Trans-Adjai areas, quartz-mica-schists and granulites are common and, when weathered, are difficult to distinguish from the finer felspathic Barakar sandstones which here rest immediately on the old Archæan land-surface. In the Trans-Adjai tract, the dip of these micaceous quartz-schists often coincides with that of the overlying basal Barakars.

Granites of the Trans-Adjai area.

In addition to the numerous dykes and sills of quartz and quartz-microcline pegmatite, Mr. Auden, in making a careful examination of the Archæan and associated rocks of the Trans-Adjai area, also noted two exposures of true granites. Besides these acid intrusions, a number of medium-grained dolerites occur massively and as dykes within the schists, and often form prominent hillocks projecting as much as a hundred feet above the surrounding country. From an examination of these basic intrusions of the Trans-Adjai tract, Mr. Auden came to the conclusion that these dolerites are quite distinct from, and much older than, those of the Rajmahal group, which also intersect the Gondwanas of the coalfield. He observes that at the base of the hill-exposures, the unaltered rock grades through a zone of amphibolitisation into true hornblende-schists. He states that :—

Dolerites of the Trans-Adjai area.

Relation of these dolerites to the hornblende-schists.

'Such an extensive alteration is incompatible with the absence of alteration in the Barakar strata of the Trans-Adjai area, and the whole series of Trans-Adjai dolerites is now regarded as belonging to the metamorphic group of rocks. They agree well with the "Newer Dolerites" of Dr. Dunn[1], of late Dharwar age..... The fact that these dolerites and hornblende-schists grade into each other assigns to them the same period in the history of the Dharwars. It follows, therefore, that most of the hills of hornblende-schist which occur on the north side of the Raniganj coalfield, belong to the same period, that is, to the "Newer Dolerites"

[1] *Mem. Geol. Surv. Ind.*, LIV, (1929).

of late Dharwar age. This series is cut up by pegmatites and quartz bodies, but is intrusive into the bedded hornblende-schists, granulites, mica-schists, etc.'

He further suggests that the metamorphism of these dolerites is the result of subsequent granite, pegmatite and quartz intrusion, subsequent shearing in post-Gondwana times having advanced this alteration.

To the south of the coalfield, within the Bankura district, these dolerite hills form prominent features of the landscape.

CHAPTER V.

GEOLOGY—*contd.*

The Talchir Series.

It is very probable that an Archæan land-mass, including the previously-described rock-types, comprised the whole area upon which the Gondwanas of the Raniganj coalfield were laid down. There is at least no evidence of any intervening beds, and had such strata ever been deposited, it is evident that they had been eroded from large portions of Gondwanaland, and the Archæans again exposed as an irregular land-surface, long before Talchir times.

General distribution.

Except in the eastern part of the field and in the vicinity of Kelyasota in the south-west, the lowest beds resting on these ancient metamorphic rocks are the predominantly dull-green, silty beds of the Talchirs, which, recognised by their singular mineral character, form the base of several of the Indian coalfields, and an important horizon in the stratigraphical succession of the Salt Range and of the Himalayan mountain chain. It is remarkable that a series of beds of such constant and unique lithology should be found at disconnected intervals over so immense an area. It is, however, very probable that, at the time of their deposition, these Talchir sediments, together with the higher Gondwanas which overlie them, formed a continuous series of deposits extending over a much larger tract of country, running approximately east to west across western Bengal, Bihar & Orissa, and Central India. What we now observe are mere remnants of those beds, owing their preservation largely to post-Gondwana faulting and subsidence.

Age of the Talchirs.

Regarding the age of these basal Gondwana strata, the evidence of the included plant-remains, of the occurrence of brachiopods of Upper Carboniferous age in the Salt Range representatives,[1] and of the recent discovery of Gangamopteris in beds well above the Talchirs and immediately below the Lower Permian limestones of Warcha, Salt Range,[2]

[1] *Rec. Geol. Surv. Ind.*, XIX, p. 127 (1886); Manual of the Geology of India, 2nd edn., p. 120, (1893); *Rec. Geol. Surv. Ind.*, XXIV, p. 19, (1891); *Op. cit.*, XIX, p. 22, (1886); *Op. cit.*, XX, p. 117, (1887); *Op. cit.*, XXIII, p. 38, (1890).
[2] *Op. cit.*, LXII, pp. 412-443, (1930).

establishes with considerable justification an Upper Carboniferous age for these Talchir sediments.

As is to be expected in the case of a series of beds of this type, laid down on an uneven denuded land-surface, the Talchirs show considerable variation in thickness, even within the Raniganj coalfield. Often the exact thickness of the group is difficult to ascertain, owing to lack of exposures, and the uncertainty of repetition by strike-faulting. There is, however, no doubt that these beds, well-represented along the northern boundary in the western and middle parts ot the coalfield, die out fairly rapidly to the east, where they are overlapped by the lower Barakar sediments.

Distribution within the Raniganj field.

The Talchir sediments of the Raniganj coalfield are exposed, therefore, as a tract of variable width adjoining the northern edge of the field. The series is well-represented in the north-western part of the coalfield, west of the Barakar river, and again for several miles to the east of the river. To the north of Panuria, however, these Talchir strata thin rapidly eastwards and finally die out within the vicinity of Kantapahari. The total area of these northern Talchir outcrops is $25\frac{1}{4}$ square miles, of which about $19\frac{3}{4}$ square miles occur west of the Barakar river, and the remaining $5\frac{1}{2}$ square miles to the east. Included within the area of Lower Gondwanas to the west of the Barakar river, small lenticular-shaped patches of Talchir rocks crop out against the main boundary fault, and again further south, to the north of the Damodar river, similar beds are exposed adjoining the Archæans. These southern areas comprise a total of about $1\frac{1}{4}$ square miles.

The Pusai and Sonbad *nala* sections.

The stratigraphical details, relating to the northern tract of Talchir sediments are as follows. In the extreme west, these beds are well-exposed in the Sonbad and Pusai *nala* sections and include, in descending order, the following types :—

(*Barakars.*)

Fine-to medium-textured, bedded sandstones and shales of greenish and brown-yellow tints, passing up into yellow and grey types, similar to those of the lowest Barakar measures.

Alternating fine-bedded sandstones and shales of a khaki-green and brownish-yellow colour ; in the lower horizons the brownish-yellow sandstones are more massive and include occasional rounded pebbles of quartzite and gneiss.

Fine, olive-green, splintery shales with some khaki-green sandstones.

Basal shale and sandstone group including rounded and sub-rounded boulders of gneiss and quartzite, varying up to several feet in diameter.

....

(*Archaeans.*)

The Metamorphic--Talchir junction, as exposed in the Sonbad *nala*, is steep—about 40°—but does not appear to be a faulted one. A short distance south of this boundary the dip decreases to about 22°, and continues at about 18° to 20° in a S. 20° to 30° W. direction up to the junction with the Pusai, at which place the basal Barakars overlie the Talchirs. The passage from these uppermost Talchirs up into the Lower Barakar beds, is very well exposed in the U-bend of the Sonbad *nala*, just before its junction with the Pusai *nala*. Allowing an average dip of about 19° throughout this section, the thickness of the Talchir series of this extreme western portion of the field is of the order of 900—950 feet.

The Jeruwadih-Ghagra boundary.

Further east, the Talchir strata extend in the form of a wide embayment, projecting north across the metamorphics up to a distance of three miles. The writer is of the opinion that the western boundary of this Talchir area, running north-east from Jeruwadih to Ghagra, is a faulted one. With regard to the metamorphic—Talchir junction of the eastern limit of this Talchir embayment, the evidence of the exposures just east of Boldih and Hariharpur villages, points to a fault or over-thrust inclined at 35° to 40°. Massive yellow sandstones with occasional pebbles of quartzite and gneiss, rest on the quartz-veined hornblende-schists, with angular fragments of schist and quartz along the junction. Intersecting the Talchir sandstones near Boldih village, a short distance west of the metamorphic boundary, are veins of white cellular quartz. These quartz veins strongly suggest that movement has taken place in the Talchir rocks, along the fracture-planes of which the quartz has been deposited from aqueous solutions. Such phenomena also indicate the possibility that the quartz-veins, which traverse the Archæans outside the limits of the coalfield, are, at least in part, of post-Gondwana age and are probably related to the compressional and tensional stresses which have imposed the present structures on the rocks

Quartz-veined Talchirs of Boldih.

Kuri *nala* section.

of the coalfield. Regarding this large area of Talchir outcrops, the succession as exposed in the Kuri *nala*, tributary to the Pusai, flowing southwards *via* Partopidih and Topatand villages, is as follows :—

(*Basal Barakars in U-bend just east of Topatand village.*)

....

Yellow-brown sandstones and sandy shales. Dip S. 36° W. at 12°.

(*Alluvium for a distance of about* ¼ *mile.*)

Opposite Dhanbad village :—

Softish brown-yellow, and greenish sandstones of fine and medium texture.

Opposite Partopidih village :— 114501

Slatey, blue-grey and brownish shales and flags, which have been quarried for slates, are exposed dipping S. 30° W. at 11°. These beds swing round to a due westerly dip in the bend just to the north. Shattered, shaly flags occur low down in the western bank of the stream a short distance beyond, then sandy alluvium for a few yards, followed by outcrops of greenish sandstones dipping N. 25° E. at 22°. Further north the dip becomes S. 30° W. at an angle of 12°. The evidence suggests a strike-fault to the south of the northerly-dipping outcrops. Typical Talchir sandstone and shale strata continue to crop out at intervals to the north, and about ¼ mile south of Janra village, massive yellow sandstones* come in including a few well-rounded pebbles. Beneath these beds are dull-green shales passing down into fine splintery shales with calcareous nodules. These strata are underlain by similar shales, a few feet thick, including boulders of quartzite and gneiss. It is suggested that these beds represent the basal beds of the Sonbad section. The dip steepens locally ; then alluvium for a few yards, followed to the north by massive, fine, yellow-brown and greenish-yellow sandstones* with fine shaly sandstones. The writer is of the opinion that these beds, north of the boulder-bearing shales, are repeated by a strike-fault, and that the two groups of massive yellow sandstones, marked * are equivalent. These sandstones continue northwards between Janra and Obchuria. Locally they include a few pebbles of quartzite with gneiss, as seen at the south-west end of the latter village. Others, to the north of the village, simulate 'free-stones' and are quarried and trimmed for building purposes. The fault, observed near Maharaidih, probably continues a short distance to the north. The dips of these massive sandstones to the east of Janra are to the south-south-west at gentle angles. Beneath these sandstones are dull-green shales, east-north-east of Ghagra. These shales are splintery below and include boulders of quartzite and gneiss, similar to the basal beds south of Janra. North-west of these boulder-bearing shale outcrops there is evidence of another strike-fault, causing the beds to be repeated further north,

Repetition by strike-faulting.

If we neglect the evidence of strike-faulting and assume that these outcrops represent a normal sequence in descending order towards the north, the succession of the Talchirs of this area must be considered vastly different from, and much thicker than that of the extreme north-western corner of the field, only 2½ miles distant. Allowing an average dip of 10°, a thickness of at least 1,800 feet of strata is indicated, including three alternating zones of massive sandstones with quartzite boulders, and three boulder-bearing horizons with a dull-green shaly matrix. Since, in the field-exposures, there is very suggestive evidence in favour of strike-faulting, it is probable that this is the true explanation of the apparently anomalous thickness of the Talchir beds of this locality. It is probable, also, that the metamorphic inliers of Barwadih and Palarpur are associated with these strike-faults.

The Pandra Khas-Mangalmara area.

Further south-east, the Talchirs continue as a broad tract, following an east-south-easterly trend, up to the Barakar river. This area was examined in detail by Messrs. Banerji and Auden. They note that the metamorphic rocks in the immediate vicinity—mainly hornblende-schists—had suffered considerable denudation during pre-Talchir times. In one case, an exposure in a tank south-east of Podadih shows the surface of these crystalline rocks to be well polished, perhaps by glacial agency. Small hillocks of these metamorphics crop out as inliers within the Talchir country near Dolalsol and Jaspur villages, while to the north of Berjor village occurs an outlier of Talchir rocks, evidently filling a depression in the metamorphics. The pebbly mudstone or boulder-bed at the base of the Talchir series, includes numerous rolled pebbles and subangular boulders, chiefly of gneiss and quartzite, but boulders of the hornblende-schist are rare. Fine-grained, olive-green shales with sandstones overlie the basal conglomerates. Near the villages of Kamlia and Madanpur, the harder types of sandstones have been quarried in the past for use as grindstones. Mr. Auden observes that in this area the upper portion of the series is almost wholly composed of sandstone, copper-green and brown-tinted below, passing up into greenish-grey types with small pebbles of quartz and gneiss. The lower sandstones include grains of undecomposed felspar and fragments of mica. The upper sandstones grade upwards into types which, except for their somewhat softer texture, are lithologically

almost indistinguishable from those of the Lower Barakars, so that the passage into the latter stage is definitely a gradual one. These uppermost Talchir sandstones are often false-bedded and weather into large pillows by a sort of desquamation or peeling off of successive layers, often independent of the original bedding-planes; their colour varies from purple to brown and white. These beds are best observed near Kanchandih, Rajpura, Kultand and Mangalmara. According to Dr. Blanford, the Talchir series, as represented near this western bank of the Barakar river, comprises a total thickness of 815 feet.

Comparing the rocks of the above-described area with those of the north-western corner of the coalfield, it is observed that the uppermost Talchirs immediately west of the Barakar river, are decidedly more arenaceous than those of the Pusai and Sonbad areas, and that the passage up into the basal Barakar beds is also more gradual than in the more western tracts.

East of the Barakar river, the Talchirs form a triangular-shaped outcrop in the vicinity of Duburdih, but further east, as far as Dendua village, the lower half of the series is cut out by the Lakrajoria-Debipur strike-fault, bringing in the metamorphics to the north. Further east near Dendua, the Lower Gondwanas are thrown northwards by a large cross-fault. East of this displacement, the whole of the Talchir group of sediments crops out across the northern portion of the coalfield to beyond Nandai village. The dip of these beds usually varies from 10° to 20° to the S. S. E., though a number of cross-faults complicate the structure of this northern tract. The general succession is, however, often well-exposed in the several stream-sections which traverse these Talchir areas, and in most cases, except in those areas adjoining the cross-faults, the junction with the metamorphics appears to be a natural one. At Basudebpur, and again just east of Bhagrand colliery, inliers of the metamorphics are exposed among the Talchir sediments. Probably the best section is that observed to the south of Dabar village. A basal conglomerate, comprising irregular boulders of felspathic gneiss of varying sizes, embedded in an arenaceous matrix, is observed resting on the crystallines. This basal boulder-bed is overlain by olive-green, fine, splintery shales which pass up into bedded shales and softish sandstones of similar green and khaki-

The Duburdih area.

The Basudebpur-Nandai area.

Section south of Dabar.

green tints. The sandstones become more massive in the upper horizons, and often include numerous grains of pink felspar. As we approach the upper part of the series, brown and yellow sandstones, including rounded pebbles of quartzite, become prominent, and these give place in the top of the Talchir series to soft, coarse-textured, felspathic, yellow, purplish and grey sandstones with occasional quartzite pebbles. Blanford estimates the thickness of these Talchir beds to the north of Paharpur, to be 320 feet. The lowest Barakar measures are very similar in character to these uppermost Talchir strata, though they include some harder bands together with a thin coal seam, exposed in the *nala* just west of Nandai. These latter beds pass up into thick pebble-bearing sandstones, a very constant and easily recognised horizon of the basal Barakars.

Stream-section near Nandai.

In the above-mentioned stream-section, just west of Nandai village, these basal Barakars overlie the grey and yellow sandstones of the topmost Talchirs with a decided unconformity, marked by a line of rounded quartzite pebbles along the junction. In the extreme north-west of this area, around Kija village, just west of the main Gourangdi-Alipur cross-fault, the basal Talchir conglomerate is silicified and indurated.

Talchirs north of Panuria.

To the north-east, in the triangular-shaped area of Lower Gondwanas, between Panuria and the Adjai river, the Talchirs have been thrown into a sharp synclinal, pitching steeply southwards, and faulted against the crystallines to the west. The basal bed, resting unconformably on the quartz-veined schists of the southern bank of the Adjai (*see* Plate No. 2), and again well-exposed in the stream-section just north of Mandira village, is a boulder-bed consisting of irregular-shaped masses of felspathic gneiss and pegmatite set in a brownish-green, felspathic, sandy matrix. Some of the boulders are well over a foot in diameter, and many of the types might well have been derived locally from the pre-Talchir Archæan land-mass. The section which follows is very similar to that noted to the south of Dabar village. Resting on the basal boulder-bed are dull-green, fine, splintery shales, weathering into acicular fragments, with lenticular-shaped inclusions of fine, white, argillaceous calcareous rock along the bedding. Massive, medium-textured, felspathic sandstones brown-green in colour, overlie these shales, and are followed above by a series of alternating sandstones and bedded

shales of dull olive-green tints. The sandstones are relatively soft-textured and are carved locally into drinking-troughs; the fine argillaceous types exhibit a characteristic concentric 'trappoid' weathering. Brown, yellow and grey, soft, felspathic sandstones, including occasional quartzite pebbles, comprise the uppermost horizons of the series. They are overlain by similar types of sandstones belonging to the basal Barakar measures, above which the pebble-bearing sandstones of the lower Barakars crop out in a prominent ridge to the north of Ramdhara village.

On account of their variable inclination it is very difficult to calculate accurately the thickness of these Talchir strata. Erring probably on the side of an over-estimate, the series, in this locality, cannot be more than 400 feet thick, again showing a very marked decrease when compared with the above-described sections of the western parts of the coalfield.

Dying-out of Talchirs north of Kantapahari.

A narrow tract of paddy-field country appears to represent the line of outcrop of the Talchir beds just north of Panuria village. This area, almost devoid of exposures, running between the metamorphic outcrops to the north, and the exposures of the basal Barakar pebble-bed to the south, narrows rapidly to the north of Kantapahari, and a short distance further east, at Jamgram, the pebble-bearing sandstones of the lowest Barakar measures, rest directly on the mica-quartz-schists of the Archæans. At no place further east, along this Lower Gondwana-Archæan boundary, are the Talchirs exposed. On the old geological maps of the Raniganj coalfield the dying-out of these Talchir strata, within this Panuria—Kantapahari area, is ascribed to an oblique strike-fault running in an east-south-easterly direction from the Adjai river, north of Panuria, and continuing to the east in the Jamgram area between the lower Barakars and metamorphics. Within the metamorphics, a short distance beyond the basal Gondwana outcrops to the south of the Adjai, such a strike-fault is observed, but, perhaps on account of the lack of exposures, there is no evidence of its continuation between these crystalline rocks and the Talchirs to the north of Panuria and Kantapahari. On the other hand, the exposures further east, to the north-east of Kantapahari and in the low ridge half-a-mile north of Kapistha, clearly show the Barakar-Archæan boundary

The question of a faulted junction.

to be an unfaulted line of natural deposition, proving conclusively that the Talchirs have died out completely in these eastern areas. Such evidence, combined with the fact that the Talchir strata tend to diminish in thickness fairly rapidly when followed eastwards across the middle portion of the coalfield, strongly suggests that the disappearance of these beds to the north of Kantapahari is not the result of strike-faulting but is due to overlap by the lower Barakar measures. The existence of a metamorphic land-mass in this north-eastern portion of the coalfield, during Talchir times, is therefore indicated.

Overlap of basal Barakars.

The details of the Talchir sediments along the southern boundary of the coalfield are as follows. The small lenticular-shaped outcrops of Talchir rocks adjoining the main boundary fault, to the south of the Kudia *nala*, include a relatively small thickness of typical green shales and sandstones with conglomerates. The dip is usually at a steep angle to the north-east, and the beds are considerably sheared; as a result, the normal sequence is interrupted and many horizons fail to crop out at the surface. In the angle between the Kudia tributary and the Damodar river, to the north of Panchet hill, the Talchir series is again represented adjoining the metamorphics which bound the coalfield. Two small outcrops occur against the boundary-fault in the vicinity of Luhchibad. South-east of this area, the continuation of this main fault appears to diminish rapidly in throw, and to be represented as a cross-fault intersecting the Lower Gondwanas of the Raghunathpur-Deilya (Deoli) area. To the south-west of this fault, to the north of the Damodar river, a tract of Talchir outcrops, of variable width, adjoins the metamorphics of the Shanrmara-Kastabad area. Olive-green shales similar to those which comprise a large proportion of the upper part of the series in the northern localities, are well-exposed, faulted against the Ironstone Shales to the north-north-west of Raghunathpur. The Talchir strata are, in this area, moderately to steeply-inclined to the east-south-east and south-east, but the thickness of beds represented, even in the northern portion of this tract, is much less than that of the Talchir representatives of the northern boundary of the coalfield, to the west of the Barakar river. Followed southwards to the Damodar, these Talchir strata diminish rapidly in thickness and, in the southern bank of that river, basal Barakar

Talchirs of the southern boundary.

beds rest immediately on the metamorphic rocks. A very clear section of the diminutive Talchir representatives is observed in the tributary *nala* just north of the Damodar river; the following succession, in descending order, is represented:—

Section, in the vicinity of the Damodar river.

(Basal Barakar conglomeratic sandstones.)

	Feet.
Soft, coarse-textured, brown, felspathic, gritty sandstones .	10
Olive-green shales	6
Dull green soft sandstones	15
Green-coloured shales	8
Sandstones, similar to those below, with few pebbles . .	30
Brownish-green, soft sandstones with rounded and sub-rounded boulders of felspathic gneiss and quartzite	18
Dark, khaki-green, soft, argillaceous sandstones . . .	3
Dark green, fine-textured shales	1
Khaki-green sandstones with small sub-rounded pebbles of gneiss and quartzite	
Total .	92

(Felspathic gneisses; with slight dip to the south-east.)

These Talchir beds dip at an angle of about 40° to the south-east. The junction with the metamorphics appears definitely to be a line of natural deposition, unaffected by subsequent earth-movements. The dying-out of these Talchir beds to the south-west, and their complete extinction to the south of the Damodar river, again points to an approach to the limits of deposition during Talchir times, and the fact that the Barakar measures, and also the Ironstone Shale beds above them, are much thinner in this area than to the north, adds further evidence to this assumption.

Fossils in the Talchirs.

Time did not permit of a detailed search for fossils within the Talchir series, and no additions can be made to the flora referred to by Dr. Blanford.[1] The latter states that:—

'The only fossils obtained from the Talchir group have been a few seed vessels and indistinct carbonaceous markings, probably of stems. These occurred at a spot in the west branch of the Nunia, close to the villages of Gopalpur and Alkusha.

[1] *Mem. Geo. Surv. Ind.*, III, Pt. 1, p. 38, (1861).

In one of the small patches of Talchir beds, which dot the country north of the Raniganj field, that on which the village of Karaon stands, a few ferns were found in a calcareous concretion. The best-marked was a form intermediate between Glossopteris and Cyclopteris....... In many places, about the middle of the Talchirs, the flags and shales which are frequently rippled, are covered with irregular pitted impressions, so much resembling footprints, that it is difficult to avoid believing them to be such. But, although frequently searched, no impressions have been found sufficiently definite to prove their origin. They are well seen on the left bank of the Barakar, above Ramnagar.'

Conditions of deposition of the Talchirs.

As has been previously mentioned in this memoir, it is extremely probable that during Talchir times, a connected area of continuous deposition followed approximately the line of the Damuda coalfields of Bengal and Bihar & Orissa, and continued at least as far west as the Gondwana regions of Central India. Dr. Fox suggests[1] that this tract of sedimentation also continued northwards to the Gondwana regions of the Darjeeling Himalayas, linking up with the Upper Palæozoic sea which covered the Shan States region of northern Burma. The occurrence of outliers of Talchir rocks outside the limits of these coalfields suggests that these basal Gondwana deposits were laid down over a much wider stretch of country than that within which they are now represented. The evidence of the marine fossils, occurring in the beds immediately overlying the Talchir sediments of Umaria, Rewah State, Central India,[2] indicates that, at least in Talchir times, this area was within close proximity of the sea; whilst the faunal relationships of these fossils suggest that this sea was separated by a land-mass from the marine facies of the Salt Range area. That glacial agencies, either in the form of actual bergs or as ground-ice, played a part in the formation of the conglomeratic deposits of early Talchir times, at least in the western part of this Damodar valley - Central India area is fairly well-established, but further east, in the Raniganj field, although the general Talchir facies is very similar to that of the western tracts, except in the instance of the polished metamorphic exposures near Podadih, the evidence points to the absence of direct glacial action. Compared with more western tracts the basal boulder-bed, in the Raniganj area, is of no great thickness. The boulders themselves are often rounded, though in some cases they

[1] *Mem. Geol. Surv. Ind.*, LVI, pp. 21-22, (1930).
[2] *Rec. Geol. Surv. Ind.*, LX, pp. 367-398, (1928).

are of irregular shape, and the majority include varieties of metamorphic rocks common to the neighbouring Archæans. Occasionally, however, small pebbles, distinct in type from any occurring in the immediate vicinity of the coalfield, are met with, including semi-quartzites and greenstones. Dr. Blanford also records the occurrence near Chargora of a boulder of clay slate containing pyrites.[1]

It is possible that the cold temperature of early Talchir times, together with the silty nature of the deposits, may explain the absence of any faunal remains within these sediments. Occasional indications of plant-life have been observed, and in uppermost Talchir times, at least in the eastern part of the Raniganj field, the advent of a Barakar facies of coarse-textured sediments has been noted. From the evidence of the Talchir and lower Barakar outcrops given above, there is good reason to suppose that during the Talchir period an Archæan land-mass existed across what is now the north-eastern corner of the Raniganj coalfield, and again to the south-west in the vicinity of the Damodar river to the north of Panchet hill.

Talchir topography.

It is probable, therefore, that a view of the topography of Northern India during earliest Gondwana times would depict an old highland land-mass, comprising rocks of the Archæan and Vindhyan systems, and covering a large part of the area west and north-west of the coalfields of Central India and the Damodar valley. During the semi-arctic conditions which prevailed in early Talchir times this mountain region formed the gathering-ground of a huge ice-mass, flows from which protruded southwards and eastwards, into a relatively shallow sea covering at least the northern portion of Central India, and resulted in the Talchir boulder-deposits of those areas which bear evidence of direct ice-action and sub-glacial conditions. East of this ice-capped mountain region a land-mass of a more subdued type of topography, probably extended eastwards into what is now Bihar & Orissa and Bengal. Within this upland tract, a wide irregularly-shaped inland extension of the sea projected along the approximate line of the Karanpura and Damodar valley coalfields into, and probably beyond, the present Raniganj area. The upland regions adjoining this tract of marine and estuarine deposition were of insufficient height to maintain an ice-cap of a size large enough to reach to the shores of this inland gulf. As a result,

[1] *Mem. Geol. Surv. Ind.*, III, Pt. 1, p. 38, (1861).

the basal boulder-beds of these eastern areas were purely of a sub-glacial origin, all traces of ice-action being removed during their transit across the land-area intervening outside the limits of the ice flows. Occasional boulders and smaller pebbles, attached to masses of floating ice derived from the bergs to the west, and transported eastwards up this inland gulf, would account for the Vindhyan and other rock types of distant origin, which are met with in the basal Talchir deposits of the Raniganj area. With the approach of a warmer climate and the consequent disappearance of the ice-caps, the silt deposits of the middle Talchir horizons were laid down, and resulted in the partial filling-up of the inland gulf and the transition to estuarine conditions, so that, as the sea receded westwards during upper Talchir times, coarser arenaceous deposits predominated, particularly in the eastern parts of the Raniganj field. Finally, at the end of the Talchir period and during early Barakar times, this area of deposition had passed into the form of a large deltaic or estuarine tract extending westwards into Central India, so that, with the advent of a climate suitable to the growth of extensive areas of vegetation, conditions amicable to coal formation prevailed during the following Damuda epoch.

CHAPTER VI.

GEOLOGY—*contd.*

The Damudas—General.

The coal-bearing strata which constitute the Damuda group of Gondwana sediments, cover a wide area, following a general east-to-west direction, across the length of the Raniganj field. Lithologically, and in a less marked degree palæobotanically, the Damudas of the Raniganj field may be divided into three series.

Classification.

These divisions were first recognised by Dr. Blanford and mapped accordingly by him, so that, except for one or two minor changes, allowing for the greater detail permitted by the new 4-inch sheets, the boundaries demarcated on his one-inch maps correspond very closely with those of the recent survey. As noted previously, these three geological divisions include :—

Upper Damudas	=	**Raniganj measures.**
Middle Damudas	=	**Ironstone Shales.**
Lower Damudas	=	**Barakar measures.**

Since they include a number of valuable coal seams, and deposits of ironstone of possible economic worth, the Damudas have naturally attracted the greatest attention of both geologists and mining

Economic value.

engineers and, as a result, on account of the fact that the iron-ore deposits have in the past been used in the blast furnaces of the locality, and the coal seams exploited increasingly during the past century, much detailed information is available regarding this group of sediments. A detailed description of the coal-bearing horizons of the Damudas, consequently forms the most important theme of this memoir. It is therefore intended to include within this chapter, only a general account of the geology of these Barakar and Raniganj beds, and to discuss in a later section (*see* Parts II and III) the details of these measures, in conjunction with the conclusions arrived at regarding the correlation of the coal seams, and the reserves of coal and iron-ore, together with the occurrence of other mineral deposits of lesser importance.

Within the areas of their maximum development, in the western and middle portions of the coalfield, the strata comprising the Damudas must be approximately 6,700 feet thick. Of these strata, the Barakar measures include approximately 2,100 feet, the Ironstone Shales 1,200 feet, and the Raniganj measures about 3,400 feet.

Thickness.

The main outcrops of the Barakar measures cover an irregular tract of country across the northern half of the coalfield. To the west of the Barakar river, these beds occupy the southern half of the Gondwana area. East of the Barakar, they continue from 1½ to 2 miles in width across the northern part of the coalfield, overlying the Talchirs, and affected in a similar manner by numerous cross-faults. With the dying out of the Talchirs near Kantapahari, the basal Barakar measures transgress on to the metamorphics of the north-eastern part of the coalfield, and continue in a similar relative position within the Sarshatali-Churulia and Trans-Adjai portions of the field. Within these eastern areas the Barakars are considerably thinner than to the west, being of the order of 1,500 feet thick at Churulia; this diminution in thickness appears to continue further east, in the south-eastern part of the Trans-Adjai area. To the south, they are overlain by the Ironstone Shale beds. These various tracts of Lower Damuda sediments comprise a total of nearly 66 square miles, including 27¼ square miles west of the Barakar river, 31¼ square miles between the Barakar and Adjai rivers, and about 7 square miles to the north of the Adjai river.

Distribution of Barakar measures.

Overlying the Talchir series to the north of the Damodar river, north of Panchet hill, and continuing against the metamorphics for a distance of 1¾ miles to the south of the river, representatives of the Barakar measures crop out over a tract of country about 600 yards wide in the north, but narrowing to the south-south-west.

Between the Barakar and the Adjai rivers, resting on the uppermost Barakar beds, though in certain areas largely hidden by a thick capping of clayey soil or alluvium, the Ironstone Shales crop out, principally across a tract of open country, free from colliery workings, from 1 to 1½ miles in width. In the western part of this area in particular, the junction between these Ironstone Shale beds and the Barakars is a faulted one, and further east the outcrops are relatively poor, so that a clear section of the actual passage from the uppermost Barakars up into the Ironstone Shales

Distribution of the ronstone Shales.

is rare, the best exposures being, probably, in the Churulia area, to the south-west of the Adjai river. This main tract of the Ironstone Shales comprises an area of about 44 square miles. Across the Adjai, in the north-eastern corner of the coalfield, alluvium covers the area to the south of the outcrops of the Barakar measures. On structural grounds, however, representatives of the Ironstone Shales would be expected beneath at least the southern portion of this alluvial tract, and this supposition is borne out by bore-holes which have penetrated the Gondwana rocks below the alluvium. The beds of this Mid-Damuda horizon appear, however, to be considerably thinner in this locality than in the above-mentioned areas further west. To the west of the Barakar river, the continuation of the Ironstone Shale beds swings round to the south-west and south, though alluvium again covers the greater part of this area. Further south, across the Luhchibad-Deilya fault, rocks of Ironstone Shale type are observed over a narrow tract between the outcrops of the Barakar and the Raniganj measures, and are well-exposed in the area south-west of Kelyasota, to the south of the Damodar river. These tracts of Ironstone Shale strata, west of the Barakar and continuing south across the Damodar, occupy a total area of about 3¼ square miles. The thickness of these beds to the south-west of Kelyasota, appears to be much less than in the northern areas.

Distribution of the Raniganj measures.

The Upper Damudas or Raniganj measures, on account of their greater thickness and, on the whole, more gentle dips, crop out over a much wider tract than do the above-described strata of the Lower and Middle Damudas. Commencing in the area between the northern foreground of Panchet hill, and the Kelyasota tract of Ironstone Shale strata, the Raniganj beds cover an area of nearly 63½ square miles to the south of the Damodar. Swinging east-north-east across this river, they continue, intersected by a number of cross-faults, over a wide tract stretching across the length of the field. They have been proved by borings as far east as Bansia, though in these eastern tracts the strata are hidden beneath a variable covering of laterite and alluvium. Within these eastern areas, therefore, the upper boundary of the Raniganj series, beneath the alluvium and laterite, can be indicated only approximately from bore-hole records. Including those proved tracts of Raniganj rocks which are now hidden by these sub-recent and recent deposits, the extent of the Raniganj measures to the north of the Damodar river

as far east as long. 87° 20′, is about 243¼ square miles. In the extreme north-eastern corner of the coalfield, bore-holes show that the lowest Raniganj beds extend beneath alluvium to the north of the Adjai river.

General lithology of the Damudas.

The following are the principal characters of the lithology of the Damudas. The rocks include varieties of fresh-water sediments ranging in type from coarse pebbly sandstones, through an admixture of arenaceous deposits, to fine shales, fireclays and coal seams. This assortment of beds was laid down during a period of relatively gradual subsidence, so that, although local unconformities in the nature of marked false-bedding are numerous—particularly in the case of the coarse sediments—no widespread hiatus can be made out, and the passage from one sub-division to the next is, on the whole, definitely transitional.

Talchir-Damuda junction.

Except in certain sections east of the Barakar river, no unconformity is visible between the basal beds of the Damudas and the uppermost Talchir rocks. In the extreme west of the coalfield, the passage between these two groups of strata is a transitional one, though taking place within a comparatively small thickness of strata. Yellow-brown sandstones with grey and greenish shales of the uppermost Talchirs pass up into grey sandstones with carbonaceous grey shales and the thick Pusai coal seam of the lowermost Barakar horizons. Further east, and again to the east of the Barakar river, the uppermost Talchir sandstones resemble the softer Barakar types more closely, so that when no local unconformity can be observed the exact boundary is somewhat arbitrary. In certain stream-sections, however, a slight discordance is noted among these beds, and this horizon has been taken as the junction between the two series.

Summary of the Barakar measures.

The arenaceous sediments of the Barakar measures are, on the whole, of a much coarser texture than those of the Talchirs and of the higher Damudas, though finer types are also met with. The sandstones are usually very felspathic and of a white or light grey colour weathering to a light yellow; they are often false-bedded, and include several horizons in which rounded pebbles, largely of quartzite, are prevalent in a greater or less degree. With these coarser beds are associated micaceous, shaly sandstones and sandy

shales of darker tints, the latter being often carbonaceous, together with seams of fine grey shale and black carbonaceous shales varying up to a considerable thickness. Intercalated in this admixture of arenaceous and argillaceous sediments are seams of coal of various qualities, the individual seams ranging in thickness up to as much as 100 feet. Seams of good quality fireclay are also included, particularly in the lower horizons of the Barakar measures, whilst bands of ironstone, varying from dark brown to dark red in colour, are met with, mainly in the upper part of the series. Though certain zones remain fairly constant, all these rock types are liable to vary laterally, the coal seams being, in many instances, irregular both in quality and thickness. The Barakar measures are best represented, and are of greatest economic value, in the western part of the Raniganj field. East of Bahira (Borrea), the majority of the coal seams of the west appear to deteriorate in quality and diminish in thickness, and in the extreme north-eastern areas, north of the Adjai river, where the Barakars as a whole are considerably thinner, only one seam of present economic value has been proved. In these eastern tracts, bands of ironstone are more numerous within the upper Barakar beds.

The Maluncha hill area.

Regarding the limited tract of Barakar outcrops on either side of the Damodar river, to the north of Panchet hill; on the north side of the river, in the stream-section above-noted (page 36), the basal Barakar strata rest conformably on the diminutive representatives of the Talchirs of this south-western area. A basal subangular conglomerate of gneiss and quartzite pebbles occurs in a yellowish sandy matrix, and is followed above by massive, grey sandstones of typical Barakar type, including a few rounded boulders, together with a coal-seam several feet in thickness. Crossing over to the southern bank of the Damodar, a bed of subangular boulders, similar to the basal Barakars of the north side of the river, rests directly on the metamorphics, and again passes up into typical coarse, massive, Barakar sandstones with fireclay, shale, and thin coal-seams. The junction is not so clear as that seen on the north side of the Damodar, but it suggests an unfaulted line of normal deposition, the basal Barakars overlapping the Talchirs to the south-west. Further south-west, indurated fireclays crop out against the metamorphics, and an inclined fault or overthrust is suggested between these two groups of strata. Above the basal pebble-bed, massive Barakar sandstones

and grits are exposed to the north-east and south-west of Maluncha hill, but, even allowing for the steep dips of these beds, the thickness of the Barakar measures of this area must be considerably less than across the north-western part of the coalfield. Carbonaceous shales, and at least one other shaly coal seam, are included in these upper measures, but, although it is possible that the outcrops of the seams are obscured owing to the 'creep' of the beds which overlie them, no evidence is available to suggest the occurrence of the thick coal seams such as are met with in the areas of Barakar rocks of the north-western part of the coalfield. The uppermost Barakar sandstones of Maluncha hill are seen to pass laterally, without any sign of faulting or overthrusting, into sandy shales and carbonaceous shales with ironstones, while the typical Ironstone Shale beds to the dip include lenticular bands of sandstone and shaly sandstone. The passage between these two series of strata in this south-western area is, therefore, a gradual one. In the present survey, the top of the massive coarse sandstones has been conveniently taken as the upper limit of the Barakars. Local unconformities naturally result from such lateral changes in the types of sediments, but no general discordance or overlap could be observed. Regarding the transition up into the Ironstone Shale series along the northern part of the coalfield, the occurrence of a large strike-fault in the Begunia-Rampur area, and the paucity of good sections across the middle portion of the field, render the question somewhat obscure. The passage is, however, exemplified in certain bore-holes (*see* Plate 16) which have penetrated through the basal Ironstone Shales, down to the Begunia coal seam, to the south of the strike-fault. It has been suggested by Dr. Blanford that this Barakar-Ironstone Shale junction is an unconformable one, but wherever field-evidence is available, no indication of an unconformity is observed. The only instance brought forward by Dr. Blanford[1] to support the opposing view, refers to the Begunia-Barakar area just east of the Barakar river. The massive sandstones overlying the Begunia seam are here markedly current-bedded, suggesting a false dip to the south at a relatively steep angle, though in reality the true dip of these measures is the same as that of the underlying Begunia seam, that is, at a gentle angle in the same southerly direction. Black carbonaceous shales

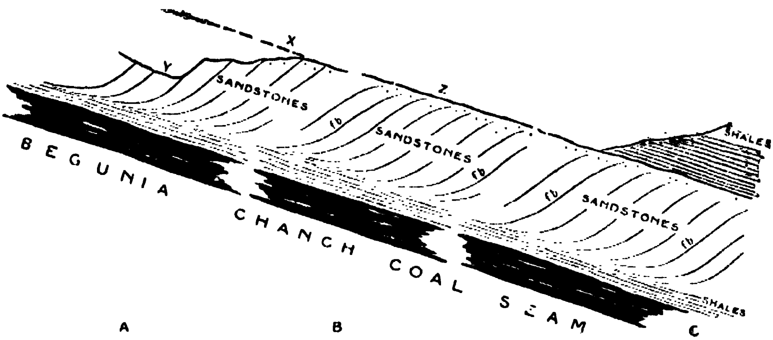
The Barakar—Ironstone Shale junction.

Exposures near Begunia.

[1] *Mem. Geol. Surv. Ind.*, III, Pt. 1, p. 42, (1861).

with occasional ironstone bands (the Begunia shales) overlie these massive sandstones, and, dipping at the same gentle angle as the true dip of these beds, they overlap the steeply-inclined current-bedded layers of the sandstone below. This phenomenon was interpreted by Dr. Blanford as indicating an unconformity between the Barakars and the Ironstone Shales. The above-mentioned Begunia shales, are, however, representatives of the uppermost Barakar measures, and are overlain to the south by thick coarse-textured sandstones and shales, including the thin coal seam equivalent to the 3-foot seam of the Begunia bore-holes. The true explanation of this succession is shown in the accompanying sketch section, taken from a short paper by Dr. Fox,[1] on this Barakar-Ironstone Shale boundary.

FIGURE 1.



A. **Exposures South of Barakar.** It is wrong to assume an anticlinal at X. This would make the beds at Y above those in the Jain temple section.

B. **Section in Quarry.** The false bedding planes, *fb*, although sharp, do not run out to the true dip slope at Z.

C. **Section at Jain Temples, Begunia.** Here dip slopes have so far only been seen. The false bedding has not been recognised in the dirty pool below the temple.

Certain of the stream-sections to the east suggest that the passage up into the Ironstone Shales is a somewhat gradual one, for the uppermost Barakar sandstones alternate with carbonaceous shales within which ironstone bands are included. The topmost bed of

[1] *Rec. Geol. Surv. Ind.*, LX, pp. 363-364, (1928).

massive sandstone has been taken as the upper limit of the Barakars and following this principle, no evidence of a general unconformity or overlap could be detected.

The Ironstone Shales.

The natural sections of the Ironstone Shales are usually very incomplete and disappointing, though several bore-holes have penetrated various horizons of the series in the area east of the Barakar river. The information available proves that these strata are of a remarkably uniform lithology, consisting of fine dark grey and black carbonaceous shales, with intercalations of sandy shale in the lower part, and numerous bands of argillaceous iron-ore varying up to about a foot in individual thickness. These clay-ironstones vary laterally, being often lenticular in occurrence. Superficially, these ironstone bands have become oxidised to a reddish-brown colour, but below a depth of about 10 feet from the surface the iron appears to be, at least in part, in the form of carbonate, the rock being dark-grey in colour. Further details regarding these deposits of iron-ore will be given in a later chapter of this memoir (*see* Chapter XVIII).

Ironstone Shale-Raniganj boundary.

The change up into the basal beds of the Raniganj measures is, at least in the western part of the coalfield, decidedly less gradual than in the case of the passage from the Barakars into the Ironstone Shales; there is, however, no reason to suggest an unconformity, at least in so far as the western and middle portions of the field are concerned. Typical dark-grey shales, with ironstones and thin sandy shales interbedded, are overlain by a thick series of massive, medium-textured, yellow-grey and greenish sandstones including lenticular-shaped bands of hard, fine-textured, sideritic sandstone. This transition is best exposed in the railway-cuttings between Kulti and Sitarampur stations.

In the extreme eastern portion of the coalfield, however, the information available indicates that considerable lateral changes have taken place within these junction beds. Unfortunately the strata concerned are, in this area, hidden by alluvium and laterite, so that one has to depend solely on the evidence of a few bore-holes which have been put down in these north-eastern tracts. The Ironstone Shales have certainly diminished in thickness, and there is good reason to believe that the basal sandstones of the Raniganj measures have likewise thinned and the included lowermost coal seams, as represented in the middle and western areas, have died

out. The evidence bearing on this question will be discussed in detail in a later chapter (page 243).

Summary of the Raniganj measures.

The Raniganj measures include a second series of sandstones, shales and coal seams. The sandstones are, however, usually of a finer texture than those of the Lower Damudas, and can usually be recognised on lithological grounds only. Coarse, white, felspathic grits and conglomerates are wanting, though, in the uppermost Raniganj horizon to the south of the Damodar river, a bed of gravelly sandstone crops out below the overlying Panchets. Occasional boulders have, however, been met with in the lower Raniganj strata. In 1906, the occurrence of a large boulder, ellipsoidal in shape, and weighing 23 lbs. was recorded.[1] This boulder was met with in the Poniati (Sibpur) seam of Damudarpur colliery. Not far distant from this locality, a much larger boulder was discovered in sinking 'D' shaft of Shibpur colliery, about half a mile south of Kaithi village. This boulder was reported to have occurred within the sandstones which overlie the Poniati seam, at a depth of 350 feet from the surface. The boulder is extremely smooth; it is ellipsoidal in shape, its three diameters measuring 13¼ inches by 9½ inches by 6 inches; its weight is 45 lbs. It is composed of a very fine-grained sandstone, reddish in colour, and resembles certain Vindhyan types. Considering its size and unique occurrence, and the fact that it is embedded in sandstones of fine to medium texture, the question of its mode of deposition is somewhat perplexing. The writer suggests that it was transported to its present position on floating timber during the process of Raniganj sedimentation. In the above-mentioned paper, a boulder is also recorded from the Gourangdi coal-seam of the lower Barakar measures. The sandstones of the Raniganj measures are normally even-textured, medium-grained, and of grey, yellow-grey, and greenish tints. Some of the lower types include numerous small grains of pink felspar. Fine-textured, hard, sideritic bands are included within these sandstones; micaceous shaly sandstones and sandy shales are prominent, and dark grey shales, with occasional ironstone bands, are also intercalated among the measures, though in a more limited degree than in the case of the Barakars. The coal seams, ranging up to an individual thickness of over 40 feet, show considerable lateral variation both in quality and thickness, but

[1] *Trans. Min. & Geol. Inst. Ind.*, I, pp. 139-146, (1907).

these changes usually take place much more gradually and the coal seams are much more constant in occurrence than in the case of the Barakar strata. Workable seams of good quality fireclay have apparently not been proved within these Upper Damuda beds, though carbonaceous fireclays are worked in the neighbourhood of Raniganj.

Petrography of Raniganj sandstones.

During the course of the present survey, Mr. Banerji carried out certain lines of research on the petrography of the sandstones of the Raniganj measures. In connection with the heavy mineral constituents, he recognised the following minerals as they occur in order of frequency;—garnet, zircon, rutile, biotite, tourmaline, monazite, apatite, and an undetermined bluish mineral. Garnet was always predominant. Regarding the results of these determinations, Mr. Banerji writes as follows:—

'On the whole, the heavy minerals do not show any marked change in character in any of the four horizons, and the flooding of garnet in all cases imparts a certain uniformity of character. Therefore, their value is negligible as a guide in correlating the coal seams by the study of the associated sandstone beds. The four horizons represent portions of the upper, middle and lower divisions of the Raniganj series and the total thickness of strata between the two extreme horizons is in the nature of 2,300 feet. It is remarkable that in this thickness the heavy minerals, especially the garnets, have maintained identical physical characters, thereby suggesting a common origin. This tends to indicate that the whole of the sandstone strata of the Raniganj series were derived from the degradation products of the same set of rocks and that there was no change in the direction of drainage throughout the period. This latter fact is borne out by the absence of any evidence of unconformity within the series.'

'Attention may also be drawn to other features of the heavy minerals. There is an entire absence of such metamorphic minerals as kyanite, sillimanite, andalusite, staurolite, cordierite, &c. Similarly, magnetite and ilmenite are absent. The majority of the minerals occurring are pyrogenetic, usually associated with igneous rocks. As regards the minerals lighter than 2·8, the examination of thin sections show that microcline is present in all cases. The sandstones are more or less arkose with a high proportion of felspar.'

Fossils of the Damudas.

Within the Damuda group of sediments of the Raniganj field and of the Damodar valley as a whole, the characteristic Glossopteris flora of the Lower Gondwanas, essentially Palæozoic in type, is well represented. Though exhibiting no detailed zonal distribution, these floras, when taken collectively, are of valuable assistance in corroborating the classification of the beds into the various major stages above-mentioned. Certain types persist throughout the Damudas, whilst

other forms are characteristic of, if not actually confined to, the upper or the lower measures. The plant fossils which are found within the Damudas include :—

Raniganj series . . .	*Gangamopteris whittiana, Glossopteris communis, Gl. indica, Gl. browniana, Gl. intermedia, Gl. ingens, Gl. divergens, Gl. conspicua, Gl. formora, Macrotaeniopteris danaeoides, Pecopteris affinis, Alethopteris, Sphenopteris polymorpha, Trizygia, Phyllotheca indica, Schizoneura gondwanensis, Vertebraria indica.*
Ironstone Shale series .	*Gangamopteris cyclopteroides, Glossopteris damudica, Gl. ampla, Gl. indica.*
Barakar series . .	*Gangamopteris cyclopteroides, Glossopteris communis, Gl. indica, Gl. browniana, Gl. damudica, Gl. ingens, Gl. intermittens, Vertebraria indica.*

Conditions of deposition during Damuda times.

Within the limits of the Raniganj field, and, so far as is known, of the coalfields throughout the Damodar valley, there is no evidence of the existence of marine or estuarine conditions at any period during the deposition of the Damudas. The strata are, in fact, all of fresh-water origin, laid down in large open flood-plains, inland lakes or swamps, the inorganic material being derived locally from the metamorphic land-masses which adjoined these areas of deposition, and which, in part, afforded a site for the growth and accummulation of the vegetation from which the coal seams have originated.

Evidence in favour of the 'drift' theory.

Regarding the origin of the coal seams of the Raniganj field, the evidence is strongly in favour of the 'drift' theory, or Allochthonous formation in contrast to the 'growth-in-situ' theory or Autochthonous formation. The phenomenon of a basal underclay, representing an old subsoil upon which the vegetation grew, is, in the majority of cases, absent, though basal fireclays occasionally underlie the coal seams. So far no examples of rhizophores or roots within the floors of the seams have been noted, though it should be pointed out that only in the sinking of shafts, and in a few instances within the underground workings, is the floor-rock extensively exposed. Again, within the seams themselves, no evidence of the existence of upright trunks or stems have been observed. A number of instances have, however, been noticed of woody stems of considerable size embedded, in a position parallel to the bedding, within the coal seams and the associated sediments. These fossil-

Inclusions of fossil-wood.

stems, within the seams, are usually in the form of ferruginised ironstone inclusions, with a thin layer of bright coal—vitrain—on the

outside, suggesting that the living cortical and cambial tissues have been converted into the vitrain, whilst within the woody interior ironstone has accumulated, in some cases rendering the cell-structure unrecognisable. Within the sandstone strata of the Damudas, silicified trunks and branches of trees are sometimes met with, particularly in a zone of massive grey sandstones near the top of the Raniganj measures. The best specimens were obtained during the excavation of the Kumarpur railway-cutting a short distance west of Asansol, and include two large silicified tree trunks identified by Dr. Sahni as belonging to the Dadoxylon genus of the Cordiatales group of Palæozoic Gymnosperms[1]. Only the woody interiors of the trunks have been preserved, the other softer tissues having been removed during transportation from the locality in which they originally grew. These fossil trunks were found lying approximately parallel to the bedding of the associated sandstone strata. Further support for the Allochthonous formation of the Damuda coal seams of the Raniganj field is noted in the phenomenon known as 'splitting' of coal seams. A seam, particularly in the case of those of the Barakar strata, when traced laterally, often splits up into several thin seams, separated by wedge-like intercalations of shale and sandstone, varying considerably in thickness. The characteristic 'banding' of many of the coal seams is often very persistent and might be suggested to indicate a 'drift' origin, representing the finer inorganic material brought down with the mother substance of the coal, and re-sorted by the action of currents, which, from the false-bedded nature of the associated sediments, appear to have been prevalent during Damuda times.

'Splitting' of coal seams.

It is suggested, therefore, that with the filling up of the inland gulf which occupied the length of the Damodar valley during Talchir times, the Raniganj coalfield and the adjoining areas were converted into large alluvial flood-plains. During the Damuda period these areas were subjected to a general subsidence, of an oscillatory character, so that at certain intervals they were extensively inundated to form wide lacustrine tracts, resulting in the deposition of the more regular and persistent coal seams and associated shale and fine sandstone deposits, mainly of the Ironstone Shale and Raniganj series. At

Conditions prevailing during Damuda times.

[1] *Rec. Geol. Surv. Ind.*, LVIII, pp. 75-79, (1925).

other periods, these inland lakes appear to have been largely filled up, resulting in alluvial swamps traversed by large meandering rivers, within which were deposited the coarse, false-bedded sandstone and conglomeratic sediments of Lower Damuda times, and, during these intervals, the formation of the more variable coal seams of limited extent, characteristic of that period, took place. Within this alluvial flood-plain, and across the surrounding country, during the periods of relative emergence, large areas of vegetation flourished, and, transported by the numerous flood-streams of the area, the mother substance of the coal was deposited over the submerged portion of these alluvial tracts.

It is probable that during early Barakar times, the country which surrounded these low-lying areas of deposition included high-land tracts upon which the remnants of the ice-masses of the Talchir period persisted. These melting ice-caps doubtless added to the flood-water by which the coarse conglomeratic sediments were transported to the alluvial valleys below. Evidence of the approach to these land-masses during Barakar times has been noted in the extreme north-east and south-west of the Raniganj field. In addition to the streams which flowed towards these low-lying tracts of Damuda sedimentation, it seems probable that, at least during the early part of the Damuda period, the general direction of the drainage of these low-lying swamps and lacustrine tracts was from east to west. This is suggested by the fact that the coal seams are more numerous and of greater thickness to the west, the heavier inorganic rock materials being deposited in the eastern portion of the field and the lighter mother substance of the coal being carried further west into the middle and western Raniganj and the more distant Jharia areas. During Middle Damuda times, more extensive submergence, and possibly a change of climate inimical to the growth of extensive areas of tree-vegetation, resulted in the silty carbonaceous shales and ironstones of probable lacustrine origin. In the case of these Ironstone Shale beds also, a diminution in thickness is apparent in the eastern part of the field and a similar phenomenon is noticed in the sandstones of the lowermost Raniganj measures which overlie them. Across the middle parts of the coalfield, these massive, thick, fine to medium-textured, Raniganj sandstones are markedly regular and persistent, but in the Chichuria-Semalya area to the south of the Adjai river the lower Raniganj strata and associated coal seams appear to have died out; it is, therefore, suggested that

up to Lower Raniganj times, deposition was limited by the approach to a land-mass in this north-eastern tract. Data of a similar nature suggest also the existence of land at no great distance from the south-western corner of the coalfield (near Kelyasota) until Middle Damuda times.

CHAPTER VII.

GEOLOGY—*contd.*

The Panchet Series.

Distribution and character.

Overlying the coal-bearing Damudas of the middle, southern, and eastern portions of the coalfield, though to a large extent hidden by alluvium within the latter areas, is an easily-recognised group of fresh water sediments, the Panchets. These beds, met with over a total area of about 78 square miles, are best exposed in the vicinity of Asansol and southwards across the Damodar river, reaching in some cases up to the southern boundary of the coalfield. With the exception of occasional included coaly fragments, they are completely devoid of coal and carbonised plant remains. In the middle and southern portions of the field this series is represented by a basal zone—the Maitur stage (Lower Panchets)—of khaki-green, and yellow-brown sediments, in some ways resembling the lower Talchirs, and an upper group—the Hirapur stage (Upper Panchets)—of soft, yellow-grey, micaceous sandstones and red clays, the latter being very characteristic of the group. This lower portion of the series appears to be from 300 to 400 feet in thickness, whilst the whole series, as exposed along the southern boundary, is probably as much as 2,000 feet thick. Dr. Blanford[1] states that:—

'The whole thickness of the group certainly exceeds 1,500 feet where fully developed, as at the base of Panchet Hill.'

The Raniganj—Panchet boundary.

The question of the Raniganj—Panchet boundary has been dealt with by Dr. Fox[2]. This unconformable line of slight overlap of the basal Panchets was originally noted by Dr. Blanford. The unconformity occurs immediately above the massive, fine-textured, fossil-wood sandstones of the Kumarpur railway-cutting and their extension to the south-west to near Junut village, just north of the Damodar river. Within these massive sandstones a carbonaceous fireclay band is included, whilst overlying

[1] *Mem. Geol. Surv. Ind.*, III, Pt. 1, p. 129, (1861).
[2] *Rec. Geol. Surv. Ind.*, LX, pp. 365-366, (1928).

these measures are khaki-green shales and yellow-brown sandstones typical of the basal Panchets. In addition, therefore, to a slight discordance, the lithological change is definite. Dr. Blanford, in mapping the area, appears to have included a portion of these uppermost Raniganj sandstones in his Panchet group, so that when first discovered, these tree-fossils were referred to the lowermost Panchets[1]. The recent re-survey has, however, shown that these beds represent the uppermost Raniganj measures, and form a characteristic horizon recognisable at a number of points both to the north and south of the Damodar river. The junction is well observed in the stream-section near Junut village, just north of the Damodar. At this point, however, the discordance is probably locally exaggerated, for in the mapping of these middle and southern portions of the field, where the exposures are most clearly observable, no large unconformable overlap could be distinguished, the horizons above and below this junction remaining fairly constant as far east as the Mohisila-Kalipahari area to the east of Asansol. Further east, however, in the Panchet areas of the vicinity of the Singaran *nala* near Andal, from the evidence of bore-holes put down by the East Indian Railway Company, rocks of upper Raniganj age are met with immediately below strata of upper Panchet type, the green shale and sandstone beds of the Lower Panchets of the Asansol area being, apparently, absent. The Upper Kajora seam —the uppermost coal seam of economic importance within the Andal area—is encountered in the borings at a much shallower depth beneath the top of the Raniganj measures than is its equivalent in the areas to the west, suggesting that the uppermost Raniganj beds are also missing. The evidence at least indicates an overlap of the Upper Panchet strata on to the Raniganj beds which underlie the alluvium of this area.

Various portions of these Panchet areas were mapped in detail by Rao Bahadur S. Sethu Rama Rau, Mr. Banerji and the writer.

Distribution of the Lower Panchets.

The lower portion of this series, 250 to 300 feet thick, is well-developed in and around the Nonia *nala* to the west and north-west of Asansol. Further south-west, in this open synclinal, these lower strata crop out to the north of the Damodar river, in the vicinity of Junut. As we approach the southern boundary of the coalfield, a complex anticlinal or series of small domes, least just north of

[1] *Rec. Geol. Surv. Ind.*, LVIII, pp. 75-79, (1925-26).

Biharinath hill, but more prominent to the east and west of that point, bring up this lower zone of Panchet strata, and also expose the uppermost horizons of the Raniganj measures. South of this area the beds roll over again, and the Panchets, dipping steeply, crop out once more at several places along this southern faulted boundary of the coalfield.

Lithology of Lower Panchets.

These lower beds—of the Maitur stage—include thick, khaki-green, silty shales and greenish-brown mudstones showing a strong resemblance to certain Talchir types. Hard calcareous bands, usually from 3 to 6 inches thick, are intercalated at intervals; these beds weather in a concretionary fashion into smooth oval-shaped boulders, well exposed on the surface just south of the Nonia, to the west-north-west of Asansol. Interbedded with these argillaceous strata are brown, micaceous, sandy shales and shaly sandstones, together with massive, soft, felspathic, false-bedded sandstones of a fine to medium texture. These latter beds often include grains of pink felspar, are yellowish or greenish-grey in colour, and resemble some of the massive sandstones of the Raniganj series. They are, however, usually free from the harder sideritic bands typical of the Raniganj measures. Pebbles are normally wanting, though just south of the Nonia, a thin bed of small quartzite pebbles was observed within these strata.

Limestones in the Lower Panchets.

Within the Lower Panchet horizons of the north-western end of Panchet hill, ¾ mile south of Baghmara village, bands of impure limestone are included. These limestones have been worked in the distant past, and were at one time used as a flux by the Barakar ironworks. At the time of the writer's visit, however, the small quarries were flooded. These beds were originally discovered by Mr. Williams, in 1845-47[1], and were later reported on in greater detail by Mr. F. R. Mallet[2]. Further information regarding these limestone occurrences will be given in a later chapter (page 303).

Distribution of the Upper Panchets.

The green-coloured basal Panchets pass up into a thick series of alternating sandstones and red and purple-red clays, within which occasional thin white clays are intercalated. Such strata comprise the Upper Panchet or Hirapur stage and are well exposed at intervals

[1] A Geological Report on the Damoodah valley, by D. H. Williams, Esq. (1850).
[2] *Rec. Geol. Surv. Ind.*, X, p. 148, (1877).

to the west and south of Hirapur, the best section being that observed in the stream flowing by the village of Bidyanandapur, southwards to the Damodar river. Across the Damodar, they are well exposed in several of the neighbouring stream-sections and again further south as we approach the line of hills marking the southern boundary of the field; in this latter area a very good section is seen in the Machkanda Jor to the north-east of the hillock of Gorangi.

Lithology of the Upper Panchets.

The sandstones of the Upper Panchets—the Hirapur stage—are, on the whole, softer and more micaceous than those of the lower stages of the Gondwanas. They are usually yellow or grey in colour, of a medium texture, very felspathic, massively developed, and often current-bedded, in some cases so pronounced as to simulate contortion. Mr. Banerji states that the direction of slope of the cross-bedding varies from west-north-west to west-south-west, and the sediments appear to have been laid down by rivers flowing from east to west. The intercalated clays vary in thickness up to about 20 feet; they are also sometimes very micaceous in character. Regarding these argillaceous deposits, Mr. Banerji writes:—

'The clays are brick-red to chocolate-red in colour, and are not calcareous. At intervals the clay-beds are banded with layers of sandy material, sometimes calcareous and of a greenish grey colour, usually 4 to 6 inches thick. Most of the tanks of the area are excavated in these clay outcrops. When the clay is boiled with a dilute solution of hydrochloric acid, most of the iron goes into the solution and the clay residue is changed to a pinkish-buff colour. Evidently therefore, the red colour is due to the presence of haematite in a fine powder or as a coating to the clay particles.'

Conditions of deposition.

Irregular purplish-grey limestone nodules are sometimes included within the red clays. These concretions have, on analysis, yielded as much as 66·8 per cent. $CaCO_3$. Mr. Banerji suggests that the red clays were deposited as such, having been derived from the denudation of ferruginous beds, and were laid down on the bottom of shallow lakes. He further states:—

'That these lakes were at least partially dried up periodically is evidenced by the banding of the red clay with sandy material. These bands are so far apart—4 to 6 feet—that they do not represent variations in seasonal rainfall but probably periods of drought at intervals of several years.'

By the disappearance of these shallow lakes over a greater period of time, the area was transformed into a wide alluvial plain traversed by large rivers which deposited the false-bedded sandstone strata

of these higher Panchet horizons. Further subsidence converted the area into lacustrine tracts and the deposition of the red clays was repeated.

Included animal-and plant-remains.

The occurrence of a bone bed within the Panchet series is noted by Dr. Blanford[1]. He observes that:—

'Just north of the village of Deoli, near Bakulia,* and about quarter of a mile East of the mouth of the Besram stream, a considerable expanse of rocks is exposed in the bed of the Damuda, South of the channel occupied by the water in the dry season, and here a bone bed was found, containing detached, and, frequently, rolled bones, vertebrae, and fragments of jaws with teeth; they are not very abundant, but a considerable number were procured. Some were also found in another spot in the Damuda, a little East of the village of Dikha, and fragments of bone were occasionally met with in other localities........

In one or two places remains of Estheria, and, perhaps, of one or two other small Entomostraca occurred in the Panchets. Plant remains are rare, but a considerable quantity were obtained from a fine, rather muddy sandstone, on the West branch of the Nunia, South of Maitur. The principal species were of *Sphenopteris*, *Pecopteris*, and other Ferns, distinct from Damuda forms, but with them, and in far greater abundance than any other form, was preserved the plant (*Schizoneura ?*) already mentioned as occurring plentifully in the Raniganj series. No Zamias or Cycads of any kind were met with, but fragments of a true *Taeniopteris* were found.'

Regarding the above-noted occurrence of fossil-plants of the Nunia stream, south of Maitur[2], occasional outcrops of Lower Panchet rocks are exposed at the point indicated on Dr. Blanford's geological map but within these beds no plant-remains could be found. It is quite probable, however, that at the time of his survey, a number of other rocks cropped out in this stream-section and that within these beds—now hidden from view by the alluvium of the *nala*—the several types of fossil-plants were discovered. What is now regarded as the Raniganj-Panchet boundary runs a short distance north of the plant locality indicated by Dr. Blanford, and a few yards within this boundary, in the uppermost Raniganj measures, numerous plant-remains are preserved in the shale and shaly sandstone strata. These fossils do not, however, include all the types mentioned by Dr. Blanford. It is therefore very probable that his discoveries were made, as indicated on his geological map, actually within the lower Panchet beds of the Maitur stage a short distance

[1] *Mem. Geol. Surv. Ind.*, III, Pt. 1, pp. 129-130, (1861) and *Pal. Ind.*, Ser. IV, 1, Pt. 1, (1865), (reprinted 1888).

* Bakulia evidently refers to the present village of Bagulia.

[2] *Mem. Geol. Surv. Ind.*, III, Pt. 1, p. 129, (1861) and *Pal. Ind.*, Ser. XII, Vol. III, Pt. 2, (1880).

south of the boundary. Ill-preserved plant-fossils were found, during the present re-survey, at a similar horizon in the Lower Panchets in the southern bank of the Mosekanda Jor, south of the village of Alkusa,[1] about one mile south of the Damodar river. These plants included species of Glossopteris and Schizoneura. Again, about half a mile south of the Damodar, near a large tank situated 660 yards south-east of Kukhrakuri village, a number of fish-scales, and small (?) Entomostracean remains were discovered within a thin band of greasy grey shale. The associated sandy shales yielded several imperfect plant-fragments similar to the types found south of Alkusa. These beds definitely belong to the Lower Panchets.

Age of Panchets.

The geological relationships of the Panchet series have been discussed at length by Dr. T. Oldham[2] in a paper published shortly after Dr. Blanford's survey, and later by Dr. Cotter[3]. Though resting with a slight unconformity on the Raniganj measures, it is probable that no great time-interval is represented by this break. From the evidence of the limited flora, of the occurrence of Dicynodont and Labyrinthodont bones and of ***Estheria minuta***, Dr. Oldham concluded that :—

> 'The Panchet group..represents the earliest portion of the great Mesozoic division in the general geological scale, or, in other words, is of about the same age as the *Buntersandstein* and *Keuper* of Europe.'

In Dr. Cotter's classification the Panchet beds are allocated to the Lower Trias.

Among the recently-discovered fish-scales of the above-mentioned Kukhrakuri locality, Dr. E. I. White has identified one specimen as belonging to the Palaeoniscid genus *Amblypterus*, a genus which has been met with elsewhere in deposits of Carboniferous and Permian age. The occurrence of this genus within the basal Panchets gives these beds a distinct Palaeozoic aspect, and suggests a Permo-Triassic age for the Panchet series.

[1] *Rec. Geol. Surv. Ind.*, LXIII, p. 207, (1930).
[2] *Mem. Geol. Surv. Ind.*, III, pp. 197-206, (1861).
[3] *Rec. Geol. Surv. Ind.*, XLVIII, pp. 23-33, (1917).

CHAPTER VIII.

GEOLOGY—*contd.*

The Supra-Panchet and Durgapur Beds.

1. *The Supra-Panchet beds.*

Distribution and lithology.

Resting on the Upper Panchet strata at intervals along the southern edge of the coalfield, is a series of coarse pebbly sandstones with subordinate clays of dark red colour. These beds, cropping out over an area of about four square miles, constitute the upper portions of Panchet, Gorangi, and Biharinath hills. Unfortunately, the slopes of these hills are largely covered by small trees and undergrowth and are strewn with numerous boulders, so that exposures *in situ*, particularly at the base near the junction with the uppermost Panchet strata, are rarely observed. In lithology, the strata include yellow-grey to red, ferruginous, felspathic sandstones, usually relatively soft-textured and becoming friable on weathering. The sandstones often include numerous rounded and sub-rounded pebbles, consisting largely of quartzite of white to pinkish tints. These conglomeratic sandstones are well-exposed on the top of Panchet and Biharinath hills, resting almost horizontally; down the southern slopes they form an almost continuous boulder-scree covering the main Archæan—Gondwana junction. Associated with these strata are bands of white, medium-textured, felspathic sandstones, and of red and brownish clay, often shaly and micaceous. Within these clays a few imperfect plant-remains were discovered by Dr. Blanford,[1] and again by Rao Bahadur Sethu Rama Rau during the present survey.

The Panchet—Supra-Panchet junction.

Regarding the junction between these Supra-Panchet strata and the Upper Panchets, which constitute the base of these hills, it is impossible, on account of the lack of exposures, to arrive at any definite conclusions. Dr. Blanford, however, suggests[2] that these conglo-

[1] *Mem. Geol. Surv. Ind.*, III, Pt. 1, p. 131, (1861).
[2] *Ibid.*

meratic sediments rest unconformably upon the Panchet strata. Such a supposition lends support to Dr. Fox's tentative suggestion [1] that these Supra-Panchet strata should be correlated with the Dubrajpur beds of the Rajmahal hills, indicating a probable Rhætic age.

Age.

Thickness.

Regarding the thickness of these Supra-Panchet beds, Dr. Blanford states as follows [2] :-

'On Panchet Hill there are not above 500 feet of these beds, but Beharinath Hill, which cannot be less than 900 feet above the surface of the country at its base, seems to be almost entirely composed of them.'

From Sethu Rama Rau's survey, and from the writer's brief examination of the area, however, it is strongly suspected that the figure given by Dr. Blanford is decidedly an under-estimate, and that the total thickness of these Supra-Panchet strata in both hill-exposures is at least 1,000, and possibly as much as 1,200 feet.

2. *The Durgapur beds.*

General distribution and lithology.

Earlier in this memoir, mention has been made of the occurrence of rocks of typical Upper Panchet type, in the vicinity of the Singaran *nala*, a short distance north of the Damodar river, east of Andal. South-east and east of these exposures, however, until we reach the wooded tracts stretching to the north and south of the Grand Trunk road eastwards from mile 114¼, alluvium forms an effective covering to the older rocks. Within these wooded areas to the north of Durgapur, however, and continuing southwards to the Damodar river, a series of soft, coarse textured, felspathic sandstones, yellow-grey to red in colour, and including small rounded, quartzite pebbles at various horizons, are exposed. Included within these sandstone strata are bands of red and white to cream-coloured clays. This association of sediments of the eastern part of the Raniganj field, has been designated the Durgapur beds.

These Durgapur strata are best exposed in the cuttings of the Grand Trunk road for some distance east of milestone 114¼, in the railway-cutting just west of Durgapur station, and within the wooded tract to the south. In the opinion of the writer, there is also good reason to regard the beds of the clay-pits of Messrs. Burn & Co., a short distance north of Durgapur station, as belonging to this group

[1] *Mem. Geol. Surv. Ind.*, LVIII, p. 63, (1931).
[2] *Op. cit.*, III., Pt. 1, p. 131, (1864).

of sediments though, as Dr. Fox has suggested, at least the upper part of the clays may be related to the laterite deposits of the locality. In these various road and railway cuttings, the sandstones, sometimes false-bedded, are massively developed. With them are associated bands of hard, orange-coloured, ferruginised types including layers with dark-coloured quartz-grains, together with intercalations of dark red clay-shales up to several feet in thickness.

To the south of the railway, near the Government fire station, white and cream-coloured clays, similar to those exposed in the Durgapur clay pits, are included among these sandstone strata. The section in the entrance to Messrs. Burn & Co.'s main clay-pit, along the trolley-line, north of the mixing-mill, and continued into the pits beyond, is as follows :—

Section in clay-pits.

	Ft.	in.
Brownish-green clayey soil	4	6
Ferruginous yellow-grey to reddish-brown sandstones, very similar to weathered types of the Durgapur series . .	9	6
Sandy clay with ferruginous sandstone bands . . .	2	0
Good quality white and yellowish clay, more plastic below; includes a number of oval-shaped nodules of argillaceous limonite, dark red to yellow in colour, showing a concentric structure in cross-section. These vary up to several feet in diameter and appear to be of a concretionary character	18	0
White and light grey clay, with quartz grains . . .	2	0
White and yellow, soft, argillaceous sandstones with purple-red ferruginous intercalations	20	0(?)

In a second pit, now flooded, situated just north of the railway to the east of Durgapur station, the clays, reported to be up to a maximum of 30 feet thick, are almost directly overlain by alluvium.

Although the areas between the clay pits and the sandstone outcrops to the north and south are covered by alluvium, so that no connected passage is exposed, the evidence of the general structure of the locality, of the observed occurrence of bands of clay of very similar type within the Durgapur beds to the south of the railway, and of the association of the clays of the pits with ferruginous sandstones of the variety met with among these Durgapur rocks, all suggests that these clay strata form a part of the Durgapur series.

Over the greater portion of the above-mentioned areas, these Durgapur beds are gently inclined. In the Grand Trunk road section the dip is to the south-west at about 5°; in the northern clay pit of Messrs. Burn & Co., Ltd., the beds are only slightly inclined to the south-west, whilst in the southern pit—now flooded—a slight dip to the north was reported,

Structure.

suggesting a shallow syncline in this area just north of the railway. Again, in the Kalipur railway-cutting west of Durgapur station, a more pronounced dip of 4° to 6° to the west-south-west is observed, and as we proceed further south, towards the Damodar river, this inclination increases to about 12°. It is significant that the dip increases as the southern boundary of the coalfield is approached.

North of the Grand Trunk road.

Continuing northwards across the Grand Trunk road, the wooded laterite-covered areas to the east of the present limits of the coalfield are intersected by a number of deeply-eroded stream-sections. Within these stream-sections, beneath the laterite and associated sub-recent deposits, soft, yellow, argillaceous sandstones of medium-texture are exposed, a distinct unconformity being seen between these sandstones and the gravel and laterite which overlie them (*see* Plate 6, Fig. 1). These sandstones are of a very uniform texture; are only slightly micaceous, and are much softer than the majority of Lower Gondwana types; they appear to be almost horizontal, though well-marked bedding-planes are rarely observed. They are well-exposed in the stream-sections on either side of the road leading north-east from milestone 116 of the Grand Trunk road to Parulia village, and sandstones of similar character are met with to the west and north-west of Bansia, in the northern part of this area. It is quite possible that these semi-consolidated sandstones belong to the same group of sediments as the Durgapur sandstone and clay beds, though the absence of fossil evidence, and of any continuous section to the north of the Grand Trunk road, renders the question problematical. Unlike the Durgapur beds they appear to include no clay bands, and the sandstones are of a somewhat different type, so that they might well be of a more recent age.

Durgapore bore-hole.

Further evidence is, however, fortunately available regarding the Durgapur beds to the west of Durgapur village. During the years 1903 to 1906 a deep bore-hole was put down by the Colliery Department of the East Indian Railway at Kalipur, 1¾ miles west of Durgapur station. The actual site of this bore-hole was inside the railway fence on the bank of the small *nala* just south of Kalipur village. This bore-hole, the object of which was to prove the coal seams of the Raniganj measures, was at first carried to a depth of 2,147 feet. At this point, owing to certain difficulties it was decided to line the hole. After this procedure, the hole was reported to have been continued to a

total depth of 3,063 feet. The cores of the early part of the bore-hole, down to a depth of 2,147 feet, were apparently examined by Mr. T. H. Holland (now Sir Thomas Holland) and the section carefully recorded (*see* below). Unfortunately no record has been found regarding the strata which were passed through in the lower portion of the hole, though it is stated that although the strata of the uppermost portion of the Raniganj series may have been reached, none of the coal seams of those measures were penetrated.[1] The section of the strata passed through in the upper 2,147 feet of this Kalipur bore-hole is as follows :--

Section of Kalipur bore-hole.

No. of sample.	Mr. T. H. Holland's description.	Thickness.	Depth.
		Ft. in.	Ft. in.
1	Yellow felspathic sandstone with some undecomposed and some decomposed felspar. Small quantity of mica flakes. Pebbles of quartz. Sandstone of medium grain	30 6	30 6
2	Sandstone slightly coarser in grain than No. 1. Quartz, undecomposed felspar crystals, mica scales and garnets. Very friable . . .	156 6	187 0
3	Clay with greenish tinge, containing scales of white and black mica	1 0	188 0
4	Dark red shale with minute mica scales and quartz granules	4 0	192 0
5	Greenish-grey, fine-grained sandstone mineralogically like No. 2 but in smaller grains. .	3 0	195 0
6	Sandstone resembling No. 2	30 0	225 0
7	Red shale with minute mica scales mottled with green spots. Pebbles and small grains of quartz	9 0	234 0
8	Sandstone, banded, dark green and dirty white, much mica, chlorite and hornblende in the green bands, decomposed felspar, garnets, &c., with quartz in the white bands . . .	17 0	251 0
9	Dark red sandy and micaceous shale with green spots	10 0	261 0
10	Sandstone, pale greenish tinge with darker bands, micaceous fine grained	12 0	273 0
11	Sandstone, greenish tinge, coarser, less friable and not so distinctly banded as No. 10 . .	10 0	283 0
12	Dark red shale with minute mica scales . .	5 0	288 0
13	Sandstone, greenish tinge, highly micaceous and well laminated, fissile. Lumps of dark red and green shales	43 0	331 0
14	Coarse sandstone with much felspar, some undecomposed, some decomposed lumps of green shale ; quartz grains sub-angular . .	5 0	336 0

[1] *Rec. Geol. Surv. Ind.*, XXXIX, p. 49, (1910) ; and *Trans. Min. & Geol. Inst. India*, VII, p. 241, (1913).

Section of Kalipur bore-hole—contd.

No. of sample.	Mr. T. H. Holland's description.	Thickness.	Depth.
		Ft. in.	Ft. in.
15	Sandstone, pale greenish tinge, imperfectly banded, sub-angular	21 0	357 0
16	Brown micaceous, well laminated sandstone with much biotite, splitting into even laminae . .	2 0	359 0
17	Sandstone with white and brown mica, some decomposed felspar, greenish colour, a few garnets	10 0	369 0
18	Sandstone with lumps of greenish garnets and undecomposed felspar	3 0	372 0
19	Similar mineralogically to No. 17 but finer in grain with casual pebbles of quartz, a streak of coal at 398 ft. 6 in. and interstitial calcite . . .	31 0	403 0
20	Olive green clay, crushed and slickensided . .	2 0	405 0
21	Olive green clay with brownish tinge, slickensided by squeezing	2 0	407 0
22	Dark green, micaceous sandstone with brown patches giving it a mottled appearance . .	1 0	408 0
23	Sandstone similar to No. 17 with decomposed felspar and garnets	2 0	410 0
24	Ditto	76 0	486 0
25	Dark olive green shale with leaf markings . .	2 0	488 0
26	Greenish sandstone with shaly patches, silvery mica, garnets, &c..	4 0	492 0
27	Sandstone with pale greenish tinge like No. 26. Coal streak at 496 ft., no shale patches . .	60 9	552 9
	Coal layer 1 *in. thick at* 538 *ft.* gave on analysis (Ward)	..	..
	Moisture 20·25 . . Sp. Gr. 1·297.		
	Vol. matter 42·00 . . Brown streak.		
	Fixed carbon 34·75 . . Sub conchoidal fracture.		
	Ash (very dark red) 3·00 Coked well, jet-like in appearance.		
28	Grey micaceous, fissile sandstone, false bedded .	0 3	553 0
29	Compact white calcareous sandstone with garnets and a single granite flake	13 0	566 0
30	Sandstone with micaceous partings, false bedded .	1 6	567 6
31	Light grey felspathic sandstone, coarse grained, with quartz crystals, a few garnets and traces of hornblende	16 6	584 0
32	Greenish grey sandstone, fine grained, with partings of black and white mica, garnets, quartz and undecomposed felspar grains . .	1 0	585 0
33	Similar to No. 31, more compact and slightly greener in colour	60 0	645 0
34	Darkish grey, fine-grained fissile sandstone, well laminated with large quantities of black and white mica at partings	5 0	650 0
35	Similar to No. 31, but somewhat coarser in grain .	15 0	665 0
36	Similar to No. 34	1 0	666 0
37	Similar to No. 31, slightly greener in colour .	1 0	667 0
38	Similar to No. 32, but with no garnets . .	1 0	668 0
39	Similar to No. 31, slightly greener in colour .	23 0	691 0

Section of Kalipur bore-hole—contd.

No. of sample.	Mr. T. H. Holland's description.	Thickness.		Depth.	
		Ft.	in.	Ft.	in.
40	Greenish-grey, fine-grained, fissile sandstone, well laminated with black and white mica at partings	2	0	693	0
41	Similar to No. 35, very friable	15	0	708	0
42	Darkish grey, fine-grained, fissile sandstone, well laminated with black and white mica at partings and with a carbonaceous fossil impression	1	0	709	0
43	Light greenish-grey, felspathic sandstone, coarse-grained, with quartz crystals and a few garnets	4	0	713	0
44	Greenish-grey sandstone, fine grained, with partings of black and white mica, garnets, quartz and undecomposed felspar	1	0	714	0
45	Greenish-grey sandstone, fine grained, garnets, quartz and felspar	28	0	742	0
46	Ditto	7	0	749	0
47	Similar to No. 46, but lighter in colour and coarser in grain	13	0	762	0
48	Light grey, calcareous sandstone, coarse-grained and very friable, with quartz, and decomposed and undecomposed felspar	5	0	767	0
49	Light grey sandstone, slightly calcareous, with few grains of mica	3	0	770	0
50	Greenish-grey sandstone, same as No. 46, but coarser in grain	41	0	811	0
51	Light grey sandstone with much black and traces of white mica, felspar and quartz	2	0	813	0
52	Greenish-grey sandstone, fine-grained, with partings of black and white mica	2	0	815	0
53	Light grey, coarse-grained sandstone with quartz, decomposed and undecomposed felspar, hornblende and garnets	7	0	822	0
54	Greenish-grey sandstone, fine-grained, well laminated, with black and white mica at partings	10	0	832	0
55	Darkish grey felspathic sandstone, fine-grained, with mica in places, soft and friable	20	0	852	0
56	Light grey, calcareous sandstone with decomposed and undecomposed felspar, quartz and garnets, and lumps of grey clay and traces of mica	15	0	867	0
57	Dark greenish-grey shale, very soft	1	0	868	0
58	Dark brownish-grey shale	1	0	869	0
59	Greenish-grey, fine grained, shaly sandstone with partings of black and white mica	3	0	872	0
60	Light grey sandstone with decomposed and undecomposed felspar, black and white mica, garnets and quartz	45	0	917	0
61	Dark green, sandy shale mottled with red shale	1	0	918	0
62	Red-brown shale with mica specks, laminated	1	0	919	0
63	Light grey sandstone, very friable with greenish bands; quartz, much decomposed felspar and many garnets	51	0	970	0
64	Greenish-grey sandstone banded with red and green shale	2	6	972	6

Section of Kalipur bore-hole—contd.

No. of sample.	Mr. T. H. Holland's description.	Thickness.		Depth.	
		Ft.	in.	Ft.	in.
65	Light grey sandstone with quartz and garnets and banded with green sandstone . . .	22	6	995	0
66	Dark green sandstone, well laminated, very soft, and full of black and white mica at partings .	1	0	996	0
67	Light grey sandstone similar to No. 65 . .	10	6	1,006	6
68	Red shale	1	6	1,008	0
69	Light grey sandstone similar to No. 65 . .	51	0	1,059	0
70	Light grey sandstone with bands of red sandstone	6	0	1,065	0
71	Red shale	3	0	1,068	0
72	Grey sandstone mottled with red micaceous sandstone	9	0	1,077	0
73	Light grey sandstone with greenish bands, soft and friable, with quartz and specks of mica .	13	0	1,090	0
74	Light grey sandstone mottled with red and brown sandstone bands, fine-grained . . .	36	6	1,126	6
75	Red shale	1	6	1,128	0
76	Light grey coarse-grained friable sandstone containing quartz, garnets, felspar and a sprinkling of mica, with red and sometimes green sandstone bands and one band of dark red shale 3 ft. thick at 1,820 ft.	835	0	1,963	0
77	Light grey sandstone with specks of orange felspar, carbonaceous streaks at 1,970′ 9″, 1,979′ 6″, 1,979′ 9″, soft and friable and fine-grained .	34	0	1,997	0
78	Dark grey, sandy shale	1	0	1,998	0
79	Greenish red shale	3	6	2,001	6
80	Greenish-grey sandstone with lumps of greenish-grey clay, some mica and specks of orange-coloured felspar and much greenish-grey decomposed felspar	75	6	2,077	0
81	Light grey, coarse-grained sandstone with quartz and orange-coloured felspar, and lumps of greenish-grey clay	5	0	2,082	0
82	Dark red clay, slickensided	15	0	2,097	0
83	Greenish-grey sandstone with much decomposed felspar, some specks of mica and a band containing lumps of greenish-red clay 6″ thick at 2,130′ 0″, very soft	16	0	2,113	0
84	Light grey sandstone with specks of mica, garnets and quartz	4	0	2,147	0

It was suggested by the late Rao Bahadur Sethu Rama Rau that these Durgapur beds were equivalent to the Panchet strata of the more western areas. This suggestion was made previous to the receipt of the above section and was based largely on the common occurrence of red clays within the two groups of sediments. The red clays of the Durgapur area occur, however, only as relatively thin bands within the sandstones as compared with the Panchet

exposures of the middle portion of the field, whilst the Panchet sandstones of this latter area are often highly micaceous and do not include pebbly horizons as is the case with the Durgapur beds. The Panchet strata, as typically exposed in the Hirapur area, appear definitely to correspond to the red clay and sandstone exposures of the Singaran *nala* to the east of Andal. The dip of these Panchet beds of the Andal area is to the south-east, and on the supposition that a similar inclination continues beneath the alluvium to the east, it is suggested that the Durgapur strata are of an age younger than Upper Panchet. This is borne out by the evidence of the above-described bore-hole. Both in the vicinity of the Durgapur railway-cutting and within the bore-hole, red clays are very subordinate. At a depth of 2,097 feet, within this bore-hole, a thick band—15 feet —of dark red clays was, however, encountered. These beds suggest an Upper Panchet lithology so that it is quite possible that the strata in the lower portion of the bore-hole (of which no details are available) are true Panchets. The evidence is, therefore, fairly conclusive in proving that the outcropping strata of the Durgapur area are post-Panchet in age.

Age of the Durgapur beds.

The question now arises as to what horizon in post-Panchet stratigraphy these beds can be assigned. In lithology they resemble in their gritty, pebbly and ferruginous character and their association with subordinate bands of red clay shale, some of the less conglomeratic Supra-Panchet rocks of Panchet hill. The fact that the dip increases as we approach the probable line of the southern boundary-fault of the field might suggest that these Durgapur strata have been influenced by the major tensional stresses which have affected the Gondwanas of the coalfield. Judged solely on this evidence, they might be regarded as equivalent to the Supra-Panchet rocks of the south-western part of the field, probably homotaxial with the Dubrajpur strata of the Rajmahal hills. Such a correlation is, however, only a very tentative one.

Absence of quartz geodes.

Associated with the laterite and gravel bed that in places overlies these Durgapur beds, a number of fragments of quartz-geodes were observed. In several instances, the occurrence of one or two specimens of such geodes lying on and among the weathered Durgapur sandstones at first suggested that they might well have been derived from the pebbly bands of the latter series. After a

careful though unsuccessful search among those pebbles that were *in situ* in these Durgapur rocks, however, the writer was obliged to come to the conclusion that the geodes were probably residual to the gravel, laterite or alluvium which once capped these sandstone exposures. Up to the present, therefore, they reflect no light on the age of the Durgapur beds.

Sandstones of Deocha, etc.

Dr. Blanford, in his memoir on the Raniganj coalfield, gives a brief description of these Durgapur outcrops.[1] He observes that:—

'Similar beds occur further to the north, beyond the More River, near Muhammad Bazar, and East of Deocha, on the Dwarka River, just south of the end of the Rajmahal Hills. Other sandstones, probably belonging to the same formation, have been noticed by Dr. Oldham and Mr. J. G. Medlicott in Baukura and Midnapur, and it is possible that the tract of sandstone lying south-west of the town of Cuttack [2] may belong to the same formation...... They are probably of very recent date, as their extension along the old coast line, and parallel to the present one, seems to point to a geographical configuration of the land very similar to that now existing.'

These observations were made in 1861. It is interesting to note that in 1877, Mr. V. Ball, in the geological map accompanying his memoir on the 'Geology of the Rajmahal hills,'[3] included the sandstone strata of the Dwarka river section, east of Deocha, in the Dubrajpur group; whilst in the vicinity of Cuttack the Athgarh (Atgar) sandstones, to which reference has also been made, were subsequently found to include a typical Rajmahal flora.[4]

Dr. Fox's opinion.

Dr. Fox accepts the post-Panchet age of these Durgapur beds and admits of their probable correlation with the Dubrajpur (Rhaetic) beds [5] of the Rajmahal area or possibly with the Athgarh (Lias) sandstones of Cuttack. He goes further, however, and is of the opinion that the Durgapur beds, perhaps as a whole but certainly the upper horizons, may be of Miocene age. In support of this view he points to the frequent occurrence of Dicotyledonous fossil wood in association with the top sandstone and the laterite mantle over the sandstone. He points to the presence of marine Miocene beds in the Garo Hills of Assam,[6]

[1] *Mem. Geol. Surv. Ind.*, III, Pt. 1, p. 138, (1861).
[2] *Rec. Geol. Surv. Ind.*, I, p. 68, (1859) and *Op. cit.*, V, p. 59, (1872).
[3] *Mem. Geol. Surv. Ind.*, XIII, Pt. 2, (1877).
[4] *Rec. Geol. Surv. Ind.*, X, p. 63, (1877).
[5] *Op. cit.*, LXII, pp. 145-146, (1929).
[6] *Op. cit.*, LI, p. 330 ; L, p. 125, (1921).

and of the believed Miocene age of the *Ostrea* limestone under Barpada in Mayurbhunj.[1] This transgression of the Miocene sea would run very close to the eastern end of the Raniganj field. The Durgapur beds might be estuarine deposits. The problem thus awaits the discovery of fossils in the lower part of the Durgapur beds even if we admit the Miocene age of the upper sandstone with the fossil wood. According to Dr. Fox, the laterite which is found in association with the upper sandstone is part of the laterite mantle which occurs from the Rajmahal hills, to the north-east, to Midnapur and Orissa, to the south-west. He considers that it is largely of post-Pleistocene age and, judging by the presence of worn fragments of quartz geodes, is of the opinion that the laterite is largely re-cemented detrital material which has been swept down the Damodar valley from the laterite-capped trappean plateaux of Neterhat and the Jamirpat of Sirguja.[2]

In addition to the suggestive evidence of fossil-wood of Dicotyledonous type found associated with the lateritic deposits, and of the known marine transgression which penetrated far within the coastal regions of north-eastern India in Miocene times, the nature of the thin band of coal which was met with at a depth of 538 feet within the Durgapur (Kalipur) bore-hole might also be brought forward as indicating a Tertiary age. The recorded description of the coal suggests that it was vitrainised vegetable matter of which the percentage of volatiles was appreciably greater than that of the fixed carbon. Such a parallel is met with only among the Tertiary coals of India, and has so far not been recorded among the coals of Gondwana age.

In this state of uncertainty the question of the age of these Durgapur beds must, for the present, remain. That they are of post-Panchet age appears quite definite; that they may be the equivalent of the Dubrajpur beds of the Rajmahal hills is possible; on the other hand, as Drs. Blanford[3] and Fox have suggested, they might well belong to a much younger group of sediments of Miocene or post-Miocene age.

Concluding remarks.

[1] *Rec. Geol. Surv. Ind.*, XXXIV, p. 44, (1906); XXXI, p. 167, (1904).
[2] *Mem. Geol. Surv. Ind.*, XLIX, pp. 8-9, (1923).
[3] *Op. cit.*, III, pp. 138-139, (1861).

CHAPTER IX.

GEOLOGY—*contd.*

Laterite and Associated Deposits.

Distribution.

Capping the higher ground of the eastern and north-eastern parts of the Raniganj field, and continuing outside the present proved limits of the coalfield, wide tracts of lateritic rock overlie the Raniganj and Durgapur strata. In addition to these main exposures, small patches of laterite and semi-lateritised rock occur over certain small tracts of the ferruginous Barakar measures of the Trans-Adjai and Churulia areas. These lateritic cappings, of very limited extent, are very superficial and of only minor importance. The description immediately below refers to the larger tracts covering the Raniganj and Durgapur rocks.

General lithology and classification.

In contrast to the adjoining low-lying alluvial areas of rice cultivation, these main lateritic areas comprise relatively barren patches of moorland and sal (*Shorea robusta*) wooded country. A characteristic of these laterites as a whole is the presence of numerous quartz grains, evidently largely of primary origin and not derived during the conversion of the rock into laterite. The purer types of laterite occur in the western areas, but further east, owing to the inclusion of a large quantity of such detrital quartz disseminated throughout the rock, the term *quartzose laterite* might be more aptly applied. In the case of certain tracts in the extreme eastern part of the field, these quartzose laterites pass into *lateritic conglomerates*, or where only feebly consolidated they might well be designated *lateritic gravels*.[1] Within these eastern tracts the lateritic conglomerates or gravels often grade downwards into beds of partially consolidated unlateritised sandy gravel, and upwards into a capping of hard consolidated quartzose laterite. As a result, the streams of these areas, after eroding their courses through the protective capping of hard quartzose laterite, usually only a few feet in thickness, cut very rapidly into the relatively loose lateritic and sandy

[1] See Fermor, *Geol. Mag.*, New series, Decade V, Vol. VIII, pp. 454-462, 507-516, 559-566, (1911).

gravels below, resulting in the formation of deeply-incised, narrow ravines, well-observed in the wooded tracts of the extreme eastern part of the coalfield. Similar, deeply-cut ravines are seen to the west, where the purer types of consolidated laterite are underlain by the relatively soft sandstones of the Raniganj measures.

Although these different types of lateritic deposits have been designated under various names, it should be noted that the change from one type to another is a gradual one, local variations in the amount of quartzose material in the mother-rock of the laterite having resulted in the purer forms or the more siliceous and pebbly varieties. In the absence of numerous analyses, no hard and fast rule regarding the percentage of free silica implied by these separate designations is possible. The terms *true laterite, quartzose laterite*, and *lateritic conglomerate* or *gravel* are, therefore, conveniently ascribed on the evidence of the rock characters discernible in the field and under the microscope, and suitably describe the various grades of ferruginous sediments included among the lateritic deposits of the Raniganj field.

Detailed lithological characters.

The principal lithological characters of these lateritic types, and of the sandy gravel beds into which they sometimes grade, are as follows:—

(*a*) *True laterite.*

In the field the purer types of laterite comprise two zones: an upper compact massive form, vermicular in structure, and usually occurring as a hard resistant capping, from 2 to 3 feet in thickness; and a lower zone of rubbly semi-consolidated laterite, varying usually up to 4 feet thick. Exposure to air appears to be an important factor in the formation of the superficial variety, the consolidating ferruginous cement, which binds the vermicular structure to form a compact mass, having been deposited by the desiccation of the concentrated iron-bearing solutions, brought to the surface by capillarity. This cloak of compact vermicular laterite rock usually includes numerous fine quartz grains, around which the limonite has been deposited in the process of lateritisation. It is, however, normally less siliceous than the zone of rubbly laterite below, the latter in many cases grading into the less siliceous varieties of quartzose laterite rock. This underlying rubbly laterite consists of an aggregate of ferruginous pellets, from $\frac{1}{4}$ to $\frac{1}{2}$ inch in diameter, only partially consolidated by a matrix of ferruginous sand or silt.

As a result, these lower laterite horizons weather readily, and in the stream-sections are usually overhung by the compact massive laterite. The structure of these pellets is not strictly pisolitic, for when examined they often do not show concentric structure, but include fragments of highly ferruginous sandstone and clay-ironstone with the corners and edges rounded and covered with a thin coating of limonite.

(*b*) *Quartzose laterite.*

The quartzose laterites include gradations between the more siliceous types of true laterites and the lateritic gravels or conglomerates. Grains of quartz, angular to subangular, form a large proportion of the rock, and pebbles of white quartz are frequent. As in the case of the true laterites, the superficial rock forms a relatively compact layer from 2 to 3 feet in thickness. On account of the much greater predominance of quartz-grains, the vermicular habit is, however, less marked, and the rock more friable than in the purer forms. In the more eastern areas, the rubbly zone below often passes downwards without a break into lateritic gravel or conglomerate.

(*c*) *Lateritic gravels and conglomerates.*

Semi-consolidated conglomerates, or gravels of medium-texture, comprising rounded and sub-rounded pebbles of white quartz-rock averaging from 2 to 3 inches in diameter, and included within a matrix of ferruginous rubbly laterite, cover wide areas of the eastern end of the coalfield. In many cases these beds pass upwards into a superficial layer of more compact, quartzose, pebbly laterite, and in certain deeply-incised stream-sections they are seen to grade downwards into a coarse gravel of similar pebbles of white quartz included in a matrix of ferruginous sand, suggesting a bank of relatively recent river-gravel. These gravel-beds are sometimes as much as 10 feet in thickness. In this non-lateritic variety of the conglomerate, angular pebbles of gritty ferruginous sandstone, identical with those occurring in the laterite, are common. These inclusions vary up to as much as 18 inches across.

From the above description it will be observed that the various types of sediments associated in the lateritic group, all grade into each other, both laterally and in depth, the coarser quartzitic varieties being usually represented in the lower portions of the section. There is, therefore, no reason to doubt that they all belong to the same phase of sedimentation and lateritisation.

Included within the laterite, and particularly within the quartzose types of the eastern areas, are angular pieces of gritty ferruginous sandstone, together with platy fragments of clay ironstone. These inclusions are usually coated with a film of reddish-brown limonite. In some instances, these boulders of ferruginous sandstone are of very considerable size, as much as several feet in diameter. They are particularly well exposed in a small stream-section just west of Srikrishnapur (*see* Plate 6, fig. 2). The ironstone fragments closely resemble types met with among the Barakar strata. These sandstone and ironstone inclusions appear to be residual to the parent rock from which the laterite has been derived. In addition to the inclusions, and to the rounded pebbles of white quartz rock, well-rounded pebbles and boulders of pinkish and brownish semi-quartzite, resembling Vindhyan types, are occasionally met with. Of greater significance is the association of quartz-geodes, usually as angular fragments, which are met with in varying numbers on the surface of the laterite at many localities. Of still greater importance, however, is the occurrence of fossil wood, which has been found by Mr. Banerji closely associated with these lateritic rocks. The wood usually occurs as large irregularly-shaped pieces and is often water-worn. Regarding these fossil wood occurrences Mr. Banerji writes :—

Other inclusions within the lateritic deposits.

Fossil wood associated with the laterite deposits.

'In several places fossil wood was found lying on the surface of the laterite, though only in one instance was it found actually embedded within the rock. The following is the list of the localities from which the specimens were collected :—

1. South of Srikrishnapur.
2. North of Laudoha.
3. North of Bhangbandh.
4. West of Banshgara.
5. *Nala* S. S. E. of Bansia.
6. North of Baragaria.
7. West of Jemua.
8. *Nala* south of Bistupur.

The wood shows considerable decay, the structure not being well-preserved. Although transverse sections show resin canals, Dr. Cotter is of the opinion that it is not Dadoxylon or coniferous wood but of Dicotyledonous type.'

As has been previously mentioned, the lateritic deposits form a relatively thin covering to the older rocks of Raniganj and Durgapur horizons. In certain quarry- and stream-sections of the Sekpur-Mangalpur-Jambad area, the junction between these lateritic cap-

Junction with the older rocks.

pings and the Raniganj sandstones is well-exposed (Plate 4). This junction is usually very definite though irregular and wavy in outline. The uppermost Raniganj sandstones immediately below the laterite are usually very soft, the felspar being largely decomposed; these altered sandstones pass down within a few feet into the normal Raniganj types. The inclusion of extraneous material in the nature of quartz pebbles, ironstone fragments, and probable geodic material, together with a number of pebbles of Vindhyan sandstone type (though the latter are very occasionally met with in the Raniganj beds) precludes the supposition that the laterite has been formed completely by the alteration of the sandstones on which it rests. The ferruginous content of these sandstones is very small so that it is probable that a very considerable influx of ferruginous material has taken place. From certain shallow diggings to the north and south of the Grand Trunk road in the vicinity of Mangalpur, white and light-grey coloured clays have been excavated apparently from beneath the laterite. On account of the workings being flooded and partly hidden by heaps of refuse, it was impossible to decide whether these deposits represented true lateritic clays. In this locality also, the mica-preidotite dyke intrusions are exposed to the level of the surface of the laterite; they themselves have weathered into white or orange-coloured vesicular 'trap', but have not been converted into laterte.

Eastern end of he coalfield.

Very good sections are seen in the deeply-cut streams on either side of the branch road running north-east from mile 116 on the Grand Trunk road to Parulia, in the eastern end of the field. The junction of the laterite and lateritic gravels and conglomerates with the underlying soft sandstones (which have been tentatively included in the Durgapur series) is decidedly irregular and sharply demarcated (Plate 6, fig. 1). These quartzite gravel and conglomerate beds are of very considerable thickness, and although the Durgapur strata include pebbles of similar type, to suppose that these gravels are wholly the residual products of the lateritisation of the pebbly sandstone beds would necessitate the alteration of an enormous thickness of these sediments. In addition, the inclusion of ironstone fragments and the association of geodic fragments (probably derived from the laterite, but so far not found within the Durgapur beds) is evidence that these lateritic deposits were not wholly derived by the alteration of the Durgapur strata.

Regarding the lower boundary of the laterite in these more eastern parts of the field, Mr. Banerji writes as follows :—

'The section below the laterite is not uniform at all places. In some localities the laterite rests on a mottled yellow-brown clay with considerable admixture of quartz grains or sandy material. There is always a well-marked line of demarcation between the clay and the overlying laterite. But the clay is not present below the laterite everywhere. In the extreme eastern part of the coalfield, the laterite more often rests on the (?) Durgapur sandstones which are usually soft and much altered. The sandstone is felspathic and slightly ferruginous; in the southern part of this area the surface of the sandstone is cut up by grooves and encrusted with a thin coating of iron oxide. Between the bed of sandstone or of clay and the laterite, there often intervenes a more or less unconsolidated bed composed of gravelly material. This bed consists almost entirely of small pebbles of quartz in coarse gritty sand. Usually there is ferruginous matter present in the matrix, but in places the colour is white with a total absence of oxide of iron. The conglomerate bed, mentioned above, is apparently a lateral variation of this bed, and when ferruginous cementing material is present it becomes a lateritic conglomerate.'

Origin of the laterite.

Regarding the origin of the parent rock from which these lateritic deposits have been formed, the inclusion of a large proportion ot material extraneous to the strata *in situ*, which underlie the laterites, points to the conclusion that the latter have not been solely derived by the alteration of the sedimentary strata of the Raniganj and Durgapur series. It appears probable that in late Tertiary or sub-recent times an admixture of sedimentary material, including quartz gravels, geodic fragments, pieces of ironstone, and a proportion of very ferruginous sand, overspread portions of the eastern part of the field and continued eastwards and north-eastwards beyond its present limits. Some of this material was doubtless of local origin, derived from the erosion of the Gondwana and Durgapur beds of the coalfield. The geodic fragments, and possibly a large proportion of the iron content, which has gone to form the laterites, indicate a derivation from the trappean lava-flows that overspread the adjoining country, and it is probable that detrital lateritic material was also brought in from the lateritic cappings that overspread these latter areas. Where the circumstances were favourable, lateritisation doubtless continued down into the underlying Durgapur and Raniganj rocks. Whether the Dicotyledonous fossil wood was included in this influx of relatively recent detrital material, or whether it should be regarded as residual to the alteration of the rocks *in situ* into laterite, is impossible to say.

The absence of laterite on the Ironstone Shales is tentatively suggested by Mr. Auden to be due to their impervious nature. There is no reason to suppose that the ferruginous sands, which constituted the parent-rock of the laterite, did not transgress over at least a part of the Ironstone Shale area. Presuming, however, that the prevailing conditions did not permit them to be converted into laterite, these unconsolidated sands might well have been removed during the period of erosion that preceded the deposition of the recent alluvium.

Absence of laterite on the Ironstone Shales.

In addition to the above-described lateritic occurrences, certain limited tracts of quartzose gravels, which cap the Panchet and Raniganj beds to the north and south of the Damodar river to the south of Hirapur, are regarded by Messrs. Sethu Rama Rau and Banerji as equivalent in age to the more eastern lateritic deposits.

Gravels adjoining the Damodar.

CHAPTER X.

GEOLOGY—*contd*

Alluvial Deposits.

Distribution and classification.

Overlying large areas of the eastern and south-eastern parts of the Raniganj field, and extending eastwards into the plain of Bengal, wide tracts of river alluvium, evidently equivalent to the similar deposits of the Gangetic plain, transgress across the laterite and Durgapur rocks on to the Lower Gondwanas of the coalfield. In addition to this main type of alluvium, local deposits of gravel and calcareous material are found in the vicinity of the main rivers of the coalfield, whilst a third type of decidedly recent age, is included in the accumulations of river sand and silt associated with these main lines of drainage.

The principal characters of these three types of alluvial deposits are as follows :—

(*a*) *Gangetic alluvium.*

Subsequent to the deposition of the ferruginous sands and gravels and their conversion into laterite, denudation appears to have resulted in the dissection of these areas. This period of erosion was followed by one of gentle subsidence during which the thick deposits of Gangetic alluvium were laid down. These deposits include a series of blue-grey and greenish-grey clays and loams thickening rapidly to the south and east, and comprise the main areas of paddy-field cultivation of the middle and eastern portions of the coalfield. In some sections, not far from the laterite exposures, the alluvium includes patches of detrital laterite, evidently derived from the rock of the locality *in situ*. These alluvial deposits attain a very considerable thickness in the extreme south-eastern part of the field, and further east, beyond the present limits of the coalfield, they probably overlie the older strata to a depth of several hundred feet.

(*b*) ***Old river alluvium.***

In the vicinity of the Barakar and Damodar rivers, patches of gravel with occasional sands occur, in some cases, well above the

present high-flood level of the river. They are well observed resting on the Panchet rocks between the Nonia and the Damodar, to the south of Asansol, and again to the south of the Damodar, near Kalikapur. Certain of these gravels have been correlated by Messrs. Sethu Rama Rau and Banerji, with the lateritic gravels of the eastern part of the coalfield, though it is probable that some at least represent the remnants of high-level terraces associated with the Damodar river and its larger tributaries. Dr. Blanford notes,[1] that these gravels are frequently highly *kunkuriferous*, especially to the west, and are represented to the south of the Damodar near Hirakund (Hirakhun) and adjoining the Barakar river near Hatinal, south of Chirkunda, and around Ramnagar, by massive beds of *kunkur*. Among the deposits of the two last-named localities, where the hardened calcareous rock forms a ridge along the bank of the river, he discovered fresh-water shells—including ***Unio marginales***, ***Paludina bengalensis***, ***Planorbis coromandelicus***, ***P. compressus***, and a small ***Bythinia***—and bones of oxen.

(c) *Recent river alluvium.*

Within, and in the immediate vicinity of the larger rivers and streams, which traverse the Raniganj field, deposits of fine sand are met with. In the case of the three main rivers, the Damodar, the Barakar, and the Adjai, these loose sediments are remarkably consistent and often attain a very considerable thickness, approaching in some instances 100 feet. They place large deposits of material well-suited for sand-stowing within easy reach of a number of the collieries of the coalfield, and in this connection will be dealt with in further detail in a later chapter of this memoir (Chap. XX).

[1] *Mem. Geol. Surv. Ind.*, III, pp. 140-141, (1861).

CHAPTER XI.

GEOLOGY—*contd.*

Intrusive Igneous Rocks.

The Gondwana rocks of the Raniganj field, and of certain of the closely-associated Damodar valley coalfields, are intersected by a number of basic and ultra-basic igneous intrusives, which, on account of their influence on the strata in general and on the coal seams in particular, have aroused the keen interest of both geologists and mining men of this country, since the early days of the coal industry. For many years, however, a close study of these intrusive rocks appears to have been somewhat neglected, and even following Dr. Blanford's survey, the two main groups—mica-peridotites and dolerites—were not differentiated. Dr. Blanford,[1] however, noted the very considerable variation in mineral character that exists among these 'trap' intrusions, and also described their peculiar modes of occurrence both as very regular dykes of varying dimensions, and as irregular veins, which 'split and anastomose', within the sedimentary strata of the coalfield. He observed also their close association, in some instances, with the faulting of the area, and their injurious effect upon the coal seams, in particular those of the Lower Damudas. Referring to the peridotite sill-intrusions, which intersect the lower Barakar rocks of the northern parts of the coalfield, east of the Barakar river, he suggested, tentatively, that certain of these intrusions are of a slightly older age than those of the remaining areas, and appear to be affected by the faults that have dislocated the lower Damuda strata of these northern tracts. In this connection he states (p. 148):—

Views held by Blanford.

'...... there is a probability of horizontal dykes preceding the upheaval of the country, while vertical dykes are of later origin. Taken altogether, the whole circumstances show it to be probable that there are two series of dykes in the Raniganj field, the older one of which is of Damuda possibly of Lower Damuda age, and the nower of the same period as the Rajmahal group.'

More recent work suggests, however, that this view needs considerable qualification.

[1] *Mem. Geol. Surv. Ind.*, III, Pt. 1, pp. 141-149, (1861).

In 1866, during his geological survey of the Jharia field, Mr. Hughes distinguished the 'mica-trap' intrusions from the basaltic and doleritic dykes; this classification has been upheld in all subsequent surveys of those Gondwana areas in which the two groups of intrusives are associated.

Hughes, 1866.

A detailed description of the two groups of intrusions, as met with in the Raniganj coalfield, is as follows:—

(*a*) *Mica-peridotites.*

Ultra-basic intrusions of mica-peridotite and lamprophyric types are met with in the Raniganj field intersecting the sedimentaries of Lower Gondwana age. Though occurring in greater abundance within the Lower Damudas, they are also widespread in the Raniganj measures and continue as a number of narrow dykes in the overlying Panchet strata of the southern portions of the field. Up to the present, no intrusions of this type have been met with in the limited outcrops of Supra-Panchet rocks of the southern boundary of the coalfield, neither was their presence noted among the Durgapur beds of the extreme eastern part of the Raniganj area. Within the adjoining metamorphics, also, they appear to be absent. Intrusive igneous rocks of similar types occur in the Jharia, Bokaro, Karanpura and Jainti fields, and have recently been found by Dr. Fox associated with the Lower Gondwanas of the Darjeeling Himalayas. None have apparently been met with in the more western coalfields, nor among the Gondwanas of the Rajmahal hills.

Distribution.

Although penetrating all varieties of the sediments of the Raniganj area, these intrusions appear to occur more prominently among the coal-bearing rocks. This is perhaps to be expected, since the coal seams would allow an easy passage for the molten magma. On account of their greater distribution within these coal measures, of their intimate bearing on the question of the mining of the coal seams, and of the additional facilities offered for their study within the mines, these ultra-basic intrusives within the strata of the Barakar and Raniganj series have received detailed examination and a very considerable literature has accrued on this subject.

Within these coal-bearing measures their mode of occurrence varies considerably. In some instances they occur as well-marked vertical dyke intrusions, very regular in direction, though usually varying in width when

Modes of occurrence.

followed for long distances. Examples of this type include, the Sitarampur-Damagaria intrusion about 30 feet in width, the 30-foot dyke of Sodepur colliery, the 60-foot dyke running north-north-west from Bara Dhemo, and certain of the larger dyke-intrusives that intersect the Raniganj measures of the eastern part of the coalfield. Such types resemble, in their mode of occurrence, the dolerite dykes of the field, and like them, they often appear to give off few or no branches and cause only very local damage to the coal seams and the associated rocks into which they have been intruded. A few instances have been met with of equally regular sill-intrusions (*see* Plate 10, fig. 1) though these are usually not more than a few feet in thickness, and have usually been intruded immediately above or below a bed of massive, hard sandstone.

Contrasting with these relatively uniform intrusives, and comprising the majority of the mica-peridotite rocks, are a number of types characterised by an irregular habit. Though of similar composition to the more constant dykes and sills, these rocks appear to have originated from a basic or ultra-basic subterranean magma of remarkable fluidity, which was injected both upwards and laterally along the bedding of the coal seams and the associated sedimentaries. From these larger bodies of intruded magma, arterial and sub-arterial ramifications were given off. These ramifications take the form of both dykes and sills, varying in the same intrusion from a few inches to over a hundred feet in thickness. These intrusions have so penetrated the strata, the coal seams in particular, as to form an intricate network within certain areas, and, as a result of their coking action, have played havoc with certain of the coal seams. In many instances, the sill intrusions occur within the coal seams as a number of large masses, lenticular in cross-section, and several feet in width, linked up by relatively regular 'feeders' only a few inches thick.

At the outcrop of those sedimentary horizons within which such a complex network of mica-peridotite occurs, there is usually some evidence of the existence of the intrusions. On account, however, of the irregular occurrence of the sills, as evidenced in the present mine-workings, and owing to the fact that the more vertical 'dyke' offshoots are often confined to only one or two horizons within the succession, or in some instances do not penetrate the roof or floor of the coal-seam, it is obviously impossible to foretell, from the surface exposures alone, the nature and distribution of the intrusions that

occur within the strata to the dip. The information given by an occasional bore-hole may likewise be misleading. Should the intersection of such a bore-hole with a certain coal seam of economic value, coincide with one of these mica-peridotite ramifications or with the coked coal or *jhama* into which the neighbouring coal has been converted, the tract is likely to be condemned, though in point of fact large quantities of unaffected coal may well occur within the surrounding area. Only by a number of relatively closely-spaced bore-holes can a true idea of the distribution of the intrusions be ascertained.

Distribution within the Barakar measures.

As previously mentioned, these irregular mica-peridotite intrusions are much more widespread within the coal seams of the Lower Damudas than within the strata of the Raniganj measures. This, it is assumed, is due firstly, to the fact that these beds were nearer the subterranean source of the magma, and secondly, to the circumstance that the relatively easily penetrable coal seams of the Barakars, alternating as they do with beds of massive hard sandstone, offered favourable conditions for the irregular sill-like intrusion of the molten magma along the bedding-planes. The principal areas in which these complex intrusions prevail within the Barakar rocks of the Raniganj field include :—

(*a*) The lower Barakar coal measures of the Barmundih, Alkusa, Itapora, Sarshatali areas, of the northern parts of the coalfield.
(*b*) The middle Barakar coal measures of the Shampur, Chatabar, Patlabari areas, west of the Barakar river ; and the Bahira and Kapistha-Madanpur areas east of the Barakar.
(*c*) The upper Barakar coal measures of the Balltara-Kendua area just east of the Barakar river.

Intimate association with the coal seams.

That the coal seams formed very favourable channels through which these widespread mica-peridotite intrusions could ramify with ease is evidenced by the distribution of these intrusives within these Lower Damuda rocks of the coalfield, for in the middle and eastern parts of the field, where the thick seams of the upper and middle measures have apparently died out, the mica-peridotite intrusions are confined largely to the lower Barakar measures within which the coal seams persist. A second, equally important tactor appears, however, to have influenced the distribution of the intrusive networks.

As noted by Dr. Blanford, these rocks appear to be closely associated with the faulting of the area, and since—as will be discussed later—there is good reason to conclude that the period of intrusion was at a time not far subsequent to the faulting of these Gondwanas, it is reasonable to suppose that the planes of fracture, along which movement took place, served, in many cases, as the main channels up which the magma was intruded, until suitable strata were reached within which the more fluid, later products of the magma might digress with comparative ease. Several instances of a mica-peridotite dyke intrusion following the line of a prominent fault have been observed in the Raniganj field. Again, in the case of the main southern boundary fault of the coalfield, to the west of the Barakar river, where the Barakar rocks are exposed abutting against the metamorphics, a number of irregular dyke-intrusions are met with within a very short distance of the line of fracture, and running roughly parallel or slightly oblique to this main dislocation. The close association of the widespread mica-peridotite intrusives of the Shampur, Chatabar, and Patlabari coal measures, adjoining this main boundary-fault appears, therefore, to be more than accidental. Faulting on a large scale is prevalent in the Barmundih tract, whilst a large strike-fault of 400 to 500 feet throw, together with minor disturbances, limits the Barakar measures of the Balltara-Kendua area. The complex sill-intrusions of the Bahira (Borrea) tract appear to be undoubtedly connected with the large mica-peridotite dyke that follows the line of the dip-fault separating the Lalbazar-Bahira areas, whilst the numerous dislocations along the northern part of the field, in the Alkusa-Sarshatali tract, might equally well have influenced the wide-spread sill-intrusions that intersect the lower and middle Barakar measures of these localities.

Intimate association with faulting.

In pointing out the intimate association that exists between these intrusives and some of the principal zones of faulting, it is not, however, suggested that such displacements can be taken as an indication of the presence of neighbouring peridotite intrusives. This is far from being the case, and, in fact, several instances are suggested where the presence of a fault appears to have limited the transgression of the intrusions. Examples of these include the fault separating the Barmundih-Ramnagar area, the latter being comparatively free from such large mica-peridotite sills; and the fault separating the Bahira-Lalbazar area. A third, the main Adjai river strike-fault,

is of still greater significance and has an important bearing on the relative ages of the faulting and of the intrusion of these ultra-basic rocks. Mention has already been made of the extensive mica-peridotite sill outcrops of the lower Barakar measures, running from Sarshatali to just north of Churulia to the south of the Adjai river. Had these intrusions taken place at a period previous to the displacement along the line of the Adjai river fault, it would have been expected that the magma would have continued upwards, to the rise, and so penetrated the equivalent coal measure horizons now cropping out in the Trans-Adjai portion of the field. Such was not the case, however, for within the latter tract of lower Barakar measures, although the main coal seam persists in quality and thickness, mica-peridotite rocks are extremely rare, and not a single sill-intrusion, comparable in size to those of the area south of the Adjai, is met with. Such evidence strongly suggests that the displacement of this Trans Adjai area of Lower Gondwana sediments had already taken place prior to the intrusion of the mica-peridotite magma, and that the zone of metamorphic rocks that, as a result of faulting, intervened between these two areas, formed an efficient barrier through which the magma was unable to penetrate.

Influence of the Trans-Adjai fault.

As previously mentioned, these complex dyke and sill-intrusions also occur, though on a less widespread scale, within the strata of the Raniganj measures. These areas of intrusion include :—

Distribution within the Raniganj measures.

(*a*) The lower Raniganj coal measures of the Sanktoriya (Sanctoria), Sudi-Kanyapur, Jamuria and Majiara areas.

(*b*) The middle Raniganj coal measures of the Majiara-Rana-Shripur area.

(*c*) The upper Raniganj coal measures of the Siarsol area, to the north of Raniganj.

The intrusions of the latter area are possibly connected with the disturbances that resulted in the several large cross-faults of the Siarsol locality.

In the case of the large mica-peridotite sill that is seen to follow the approximate horizon of the 7-foot Shripur seam of the middle Raniganj measures, it is strongly suggested that this intrusion has been displaced by the several large cross-faults that intersect the sedimentary strata of this area. The alternative explanation is, that the intrusion has, for some unknown reason, selected the same

Intrusions questionably affected by cross-faults.

horizon throughout this disturbed tract, though why it should have done so is difficult to explain. The intrusion appears to be largely confined to the Shripur seam, relatively thin and of inferior quality, whilst lower coal seams of considerably greater thickness and of a much superior quality, have remained largely unaffected. Unfortunately, the outcrops are relatively poor, so that it is not possible to observe the exact relations between these intrusions and the several cross-faults.

A somewhat parallel phenomenon was observed in mapping the large peridotite sill that occurs within the lower Barakar measures of the Sarshatali-Churulia area. A number of relatively minor cross-faults intersect the strata, and the outcrops of the sill, keeping as they do to approximately the same horizon within these measures, suggest that these minor displacements are subsequent in age to the intrusion. The sill intrusions within the middle Barakar measures between Madanpur and Sarshatali are also suggestive in a similar manner. In the case of the Sarshatali-Churulia area, however, it should be mentioned that the mica-peridotite appears to follow closely the probable line of outcrop of the main coal seam of that area, so that the marked preference that the sill-intrusions exhibit for the coal seams may, in this instance, supply the necessary explanation of their apparently faulted character.

In some cases, the more vertical mica-peridotite dyke intrusions transgress directly across a line of faulting, proving them to be of an age subsequent to these displacements.

As in the case of their mode of occurrence, so in their physical characters, these ultra-basic intrusives show considerable variation.

Physical characters.

This is the result of, firstly, differences in the mineralogical composition of the intrusions at the time of injection, and secondly, varying degrees of weathering. In no instance was a specimen totally unaffected by atmospheric weathering met with in the Raniganj field. The least altered types, derived from the interior of several of the larger intrusions, were of a fine, hard texture, blue-grey to greenish in colour, with prominent olivine, and in some cases, abundant bronze biotite. The outer portions of such intrusives were usually weathered to a brown or yellow colour. In other instances, the whole of the intrusion, as seen at the outcrop, assumed variegated red-purple to yellowish tints, was relatively soft and porous, and so closely simulated a sandstone habit that to the untrained eye such specimens

were, in the field, very liable to prove deceptive. Other examples were met with from which the iron content had, apparently, been almost totally removed, the resulting rock being somewhat vesicular and of a white to light grey colour. Within the coal mines these dyke and sill-intrusions were usually extremely hard and costly to penetrate; but in the case of a few small dykes, up to about one foot in thickness, the rock had been decomposed into a soft, white or light coloured 'clay', which was used by the miners for white-washing their houses.

Petrological characters.

The petrology of the ultra-basic intrusives of the Raniganj and associated Damodar valley coalfields has received the attention of several earlier writers. The first microscopical examination was made by Mr. F. Rutley, in 1880.[1] Mr. P. N. Bose, in 1888,[2] described three specimens obtained from Laikdih and Raniganj, under the name 'Kersantites'. Later, in 1894, Sir Thomas Holland[3] examined similar material collected in the Giridih field and, as a result, suggested that the name 'mica-peridotite' was more correctly applicable to this group of intrusions. In 1916, Dr. Fermor described certain types from Bokaro as apatite-minette and mica-peridotite. More recently, Dr. Fox,[4] in adding to the literature on the subject, indicated that the name 'mica-peridotite' is liable to be somewhat misleading when applied collectively to the different varieties of this ultra-basic series.

During the recent re-survey of the Raniganj field, the examination of a number of specimens was carried out principally by Messrs. Banerji and Auden who, after including in their investigation Sir Thomas Holland's specimens, state as follows :—

Variation in mineralogical composition.

'There is a great variety of type. In the field, the bulk of the rocks are lamprophyric in appearance with coarse and finely crystalline types sporadically distributed, with or without visible phenocrysts of olivine. These are frequently cut up by veins almost free from biotite. In addition, there are a large number of exposures, especially of sills, of fine-grained "sandstone" weathering rock without visible mica, and more rarely dykes of amygdaloidal non-micaceous rock were observed. The colour ranges from the dark peridotitic rocks of Giridih to the more usual glittering lamprophyres, and to brown and green varieties. Microscopical examination fully confirms this wide variety of types, both in regard to slices from different

[1] *Trans. North. Eng. Inst. Min. & Mech. Eng.*, XXX, p. 13, (1880).
[2] *Rec. Geol. Surv. Ind.*, XXI, p. 163, (1888).
[3] *Op. cit.*, XXVII, p. 129, and XXVIII, p. 121, (1895).
[4] *Op. cit.*, LIX, p. 371, (1927).

specimens, and to different parts of the same slice. The following characters may be tabulated in a general description.

1. Every gradation exists between rocks characterised by abundance of olivine (always as pseudomorphs), scarce olivine, and an absence of olivine. The pseudomorphs after olivine are very variable, commonly being :--
   a. Centres of calcite with margins of limonite.
   b. Centres of quartz, with cracks of limonite and carbonates, and with margins of limonite.
   c. Serpentine.
2. Felspar is probably a more important constituent of the rocks which have been recently found than of those originally described by Holland. Its determination is frequently difficult, especially in the large number of specimens in which it is thought to occur with brush extinction in turbid interstitial patches together with chlorite, quartz, carbonates and ilmenitic material. In a few cases, however, the presence of felspar is certain, as when it occurs in veins as needles in spherulitic intergrowth with quartz. On analysis, an almost biotite-free vein gave a potash percentage of 4·87 and soda of 1·02. Since there is little biotite to cause such a percentage of potash, it is concluded that the potash is present in orthoclase felspar. Water-clear microlites, scattered throughout some of the slices, appear also to be orthoclase.
3. Quartz, as just mentioned, occurs intergrown with felspar, and in the interstitial patches associated with chlorite, carbonates, ilmenite and probable felspar. It also occurs frequently in veins as perfectly clear crystals associated with rhombohedra of carbonates. Holland believed that the presence of quartz was due to the weathering of the rock resulting in the liberation of silica and the removal of the soluble bases. While this explanation may hold for specimens which are decidedly weathered, it seems better to regard the quartz in the fresh specimens as a final crystallisation product of the magma.'

'More work is required before the rock types found in the intrusions in the Damuda sediments can be properly classified. Consideration of aplitic veins alone might tend to over-emphasise the importance of the later products of crystallisation, but the work that has been done up to date goes to show that such late products are not confined to these veins but occur throughout the base of most of the specimens. While the term *mica-peridotite* is applicable to the specimens (mostly from the Giridih coalfield) which were examined by Holland in 1894, it appears that many of the rocks subsequently found in the Raniganj coalfield cannot be so designated. Some of these latter rocks may be described as *lamprophyres*, of minettic and perhaps of kersantitic types ; whilst others, without mica, belong neither to the mica-peridotites nor to the lamprophyres. As Holland pointed out in 1894, apatite is rarely absent in any of the rocks, and is sometimes extremely abundant.'

Designation of the various types.

From a petrological point of view, therefore, it appears that the name 'mica-peridotite' cannot be strictly applied to embrace all the varieties of this group of ultra-basic intrusives. As a convenient mining term the designation

The term 'mica-trap.'

'*mica-trap*' might be applied, to distinguish these rocks from the more easily-recognised 'trap' or dolerite dykes.

Analyses.

Several analyses of the less-altered types of mica-peridotite have been carried out. The following, previously published by Dr. Fox,[1] refer to the Raniganj field.

—	I. P. C. R.	II. S. K. C.	III. S. K. C.
SiO_2	27·78	44·21	36·53
TiO_2	3·48	2·24	1·80
Al_2O_3	7·33	9·11	14·08
Fe_2O_3	4·70	3·77	5·63
FeO	6·82	8·07	6·26
MgO	16·95	7·84	7·20
CaO	10·02	7·60	8·51
Na_2O	0·75	1·29	1·70
K_2O	3·77	4·73	1·18
H_2O (moist.)	1·06	3·01	5·70
H_2O (comb.)	1·39	0·38	1·05
CO_2	11·91	4·99	6·14
P_2O_5	4·38	2·77	4·13
TOTAL	100·34	100·01	100·01
Specific gravity	3·01	2·72	2·60

P. C. R.—Mr. P. C. Roy, Asst. Curator, Geological Survey of India.
S. K. C.—Dr. S. K. Chatterjee, Asst. Supdt., Geological Survey of India.
I. Typical mica-peridotite, Mugma area.
II. Mica-peridotite from Bahira colliery, near Kulti.
III. Peridotite dyke with mica in Dishergarh seam, Dharmma nala.

Dr. Fox notes that—'all analyses show traces to ·17 per cent (III) MnO; BaO is also present when looked for. In none of the samples could any peridote (olivine) or recognisable augite be detected in microscope sections. Bronze mica is present abundantly in I and II, less so in III. Apatite is common in all, but is most conspicuous in I and III. Serpentine is seen in almost all the slides. Its occurrence appears to be intimately related to areas in which olivine has decomposed and also to patches in which calcite (dolomite) is now present.'

[1] *Rec. Geol. Surv. Ind.*, LIX, 402, (1927).

Allowing for the damaging effects on the coal seams, which by reason of their peculiar composition would be readily affected by any appreciable rise of temperature, it is rather remarkable that these ultra-basic intrusives, occurring as they often do as masses of very considerable thickness, have caused comparatively little mineralogical alteration of the sedimentary strata with which they have come in contact. The sandstones in their immediate vicinity have been considerably hardened, in some cases approaching semi-quartzites, and the argillaceous beds locally baked and indurated, but little or no accompanying mineralogical changes were observed. In a few instances, angular fragments of Barakar sandstone, felspathic gneiss, and pegmatite, several inches in width, evidently caught up in the intruded magma, were included within the larger dykes. In these cases the sandstone fragments were again considerably hardened, but otherwise the specimens were unaffected.

Metamorphic effects.

In their thermal effects on the coal seams, the results vary considerably. In the case of certain of the larger, more regular dyke intrusives, the seam has been caked, or partially caked to form a natural coke of variable composition, termed in local nomenclature *jhama*, for a distance of only a few feet on either side, a distance small in comparison with the total width of the intrusion. An equally wide zone of *jhama* is, however, often met with adjoining the smaller irregular intrusions, even though these may be only a few inches in thickness, and as a result of the abundance of these anastomosing arterial and sub-arterial ramifications within certain areas, several of the most valuable coal seams, both of the Barakar and of the Raniganj measures, have been so largely converted into *jhama* that they cannot, at the present time, be profitably extracted. As will be noted from the analyses given below, even the caked *jhama* coal immediately adjoining the intrusions, still includes a small percentage of volatile matter. From the above-mentioned metamorphic characters, it is, therefore, quite obvious that the temperature of the peridotite magma was comparatively low at the time of injection. In this connection Dr. Fox states [1]:—

Thermal effects on coal seams.

'Basalt fuses at about 1000° C., whilst the fusing point of peridotite is probably less. The evidence of the volatile material remaining in natural coke (*jhama*) at

[1] *Mem. Geol. Surv. Ind.*, LVI, p. 142, (1930).

the contact with the intrusions, suggests that the fluid mica-peridotite was probably lower than 1200° C. or even less than 1000° C.'

On the other hand, the mode of occurrence of these ultra-basic ramifications proves conclusively that the magma was in an extremely fluid condition at the time of its injection. Representing, as these irregular injections apparently do, the end product of this intrusive series, it is probable that the volatile matter of the magma—doubtless including a large proportion of superheated steam—was highly concentrated, and influenced the degree of metamorphism not only by increasing the mobility of the magma, but also by penetrating the adjoining coal and causing its partial distillation.

Literature on the subject of *jhama*.

This question of the conversion of the coal into *jhama* by the metamorphic action of these ultra-basic injections, has been previously discussed at considerable length by Sir Thomas Holland (in his papers previously referred to), Dr. Fermor,[1] and more recently by Dr. Fox, both in his memoir on the Jharia field,[2] and also in two interesting papers published in 'Capital', during 1929.[3]

In the above-mentioned publications, the two latter writers have done much to clear up the misunderstanding that has arisen in the past regarding the terms 'natural coke', '*jhama*', and 'burnt coal', all three of which have at one time or another been used synonymously in referring to the naturally caked coal of those seams of the Damuda valley coalfields that have been affected by these ultra-basic dykes and sills.

Physical characters of *jhama*.

In physical character, the *jhama* immediately adjoining these intrusions closely resembles in its dark or silvery-grey colour, and its prismatic structure, the metallurgical coke used in the blast furnaces. Unlike such artificially-formed coke, however, it is—unfortunately from a mining point of view—extremely hard and very compact. Further away from the intrusion, however, the *jhama* is of a softer texture, though the stratification of the coal has been destroyed, whilst at increasingly greater distances the percentage of volatile matter increases so that at a point, varying up to several feet away from the mica-peridotite, this partially caked coal passes gradually into the unaltered seam.

[1] *Trans. Min. Geol. Inst. Ind.*, XII, p. 58, (1918).
[2] *Mem. Geol. Surv. Ind.*, LVI, p. 128, (1930).
[3] *Capital*, 27th June 1929 ; 29th Aug. 1929, pp. 507-509.

In the case of the *jhama* of the Laikdih quarries, Mr. Bose[1] gives two analyses of this columnar contact coke, together with one analysis of the normal unaltered coal. The details of these assays are as follows :—

Analyses of *jhama*.

	Columnar coke.		Normal coal.
	Per cent. (1)	Per cent. (2)	Per cent.
Water	3·38	2·98	2·48
Volatile matter	9·02	7·62	28·72
Fixed carbon	68·60	78·00	60·20
Ash	19·00	11·40	8·60

Peridotite sill in Bahira quarry.

An interesting example of the similar effects that have resulted from the intrusion of a series of lenticular-shaped mica-peridotite sills in the upper part of the 15-foot seam (Bahira 5 seam), exposed in the quarry about seven furlongs west-north-west of Bahira (Borrea) village, is described below. The coal seam is overlain by a bed of massive, hard, Barakar sandstone. Along the south side of the quarry the sill of mica-peridotite (*see* Plate 9), although keeping to approximately the same horizon within the coal seam, varies considerably in size. In places it is only from 2 to 4 inches thick, but it swells out at varying intervals into ovoid masses as much as 20 inches in diameter. The coal in contact, for a thickness of from 3 to 4 inches, has been partially caked, and occurs as hard dense *jhama* showing marked columnar jointing. The peridotite itself is also much decomposed, being of a whitish-yellow colour and fairly soft. The iron-content of the rock has been leached out by percolating water and has caused the discoloration of the coal seam along its numerous joint and cleat faces. The intrusive lenticle (P), had in the instance referred to, expanded within the uppermost part of the seam so that it almost came into contact with the roof sandstone. The coal (A), immediately surrounding the intrusion, had become partially caked for a distance of about three inches to form a very hard, compact *jhama*, but outside this narrow zone the seam was apparently unaltered. Above the mica-peridotite intrusion, however, projecting from either side into the hard sandstone, were two 'stringers' of hard coal (B. B[1]) evidently representing offshoots from the top of the seam. Samples were taken of the unaltered coal, of the *jhama*

[1] *Rec. Geol. Surv. Ind.*, XXI, p. 163, (1888).

(A), and of the coal 'stringers' (B. B[1]). These, on analysis, gave the following results :—

	Unaltered coal. (C)	Jhama. (A)	Coal 'stringers.' (B. B[1])
	Per cent.	Per cent.	Per cent.
Moisture	1·47	1·96	1·15
Volatile matter	29·45	13·68	21·55
Fixed carbon	50·56	56·13	57·04
Ash	18·52	28·23	20·26
Specific gravity	1·39	1·68	1·48
Caking properties	Cakes fairly strongly.	Does not cake.	Cakes.

(Analyses by Mr. A. K. Banerji.)

The phenomenon represents an interesting instance of the relative heat conductivity of hard sandstone as compared with that of coal. It has previously been mentioned that the caking effect in the coal adjoining the peridotite intrusion is represented in a zone of not more than three inches width ; beyond this the coal is apparently unaltered so far as the heat action of the intrusion is concerned. On the other hand, the close-grained roof sandstone, about 7½ inches thick above the peridotite lenticle, has allowed sufficient conduction of heat as to cause the partial caking of the coal 'stringers' (B. B[1]) not only immediately above the intrusion, but also extending on either side for a distance of several feet. Such phenomena indicate a heat conductivity factor for the sandstone several times greater than that of coal.

White efflorescence from the decomposed mica-peridotite.

With the decomposition of the peridotite, accompanied by the leaching action of percolating water, an efflorescence of a white, crystalline substance was deposited on the exposed faces of the intrusion and of the adjacent coal. This efflorescence on analysis gave the following results :—

	Per cent.
Silica (SiO_2)	5·71
Alumina (Al_2O_3)	0·87
Ferric oxide (Fe_2O_3)	1·06
Magnesia (MgO)	16·83
Lime (CaO)	2·97
Sulphur trioxide (SO_3)	31·67
Chlorine (Cl)	trace
Water at 110° C.	30·64
Water of combination	9·78
Phosphoric oxide (P_2O_5)	0·82
	100·35

The substance is therefore chiefly magnesium sulphate with some calcium sulphate, calcium phosphate, etc. The relatively high percentage of the phosphate further demonstrates the effect of such intrusions on the phosphorus content of coal in their immediate vicinity, as recently described by Dr. Fox, in connection with the coals of the Giridih field.[1]

A similar saline efflorescence has been observed in a number of instances in the underground workings of the various seams. It was met with both on the weathered surfaces of the intrusions and also along the cleats of the coal in the adjoining galleries. An interesting example occurred in the case of Ramnagar colliery where the Ramnagar seam was overlain by a sill of mica-peridotite rock. In this instance, the writer was informed, the water which percolated into the mine was sufficiently charged with magnesian sulphate as to temporarily affect the health of the miners who drank it.

In his memoir on the Jharia field,[2] Dr. Fox includes a number of analyses of *jhama* collected from the seams of that area that have suffered intrusion. These specimens range from types that include only about two per cent. of volatile matter, and were apparently adjacent to the intrusions, to others of more distant origin containing a far greater percentage of volatiles.

(*b*) *Dolerites.*

Mode of occurrence and distribution.

Distinct from the mica-peridotite intrusions, are a number of very regular vertical, and occasionally inclined, dyke intrusions of doleritic or basaltic type, varying from a few feet up to 150 feet in thickness. These rocks not only traverse the Lower Gondwana strata of the Raniganj field, but continue beyond the limits of the coalfield into the Archæan metamorphics. Again, unlike the ultra-basic series, these igneous intrusives exhibit the following characteristics :—

i. In no instance do they occur as irregularly-shaped sill-like masses, but invariably follow a very definite trend, traceable for many miles among the outcropping sedimentary and metamorphic strata.

ii. They intersect all the varieties of sediments alike, showing no marked preference for the coal seams as is the case of the ultra-basic intrusives.

iii. They appear to be in no way connected with the faulting that has affected the Gondwana strata, and from the fact that they cut directly across those displacements they are definitely of an age subsequent to these earth-movements.

[1] *Rec. Geol. Surv. Ind.*, LIX, pp. 371-404, (1927).
[2] *Mem. Geol. Surv. Ind.*, LVI, pp. 128-146, (1930).

iv. Offshoots from these doleritic dyke intrusions are rare, and where such branches do occur they also show marked regularity and usually follow a very definite direction.

v. Their metamorphic effects on the adjoining strata include only the slight local induration of the sandstones and shales, and the crushing and partial caking of coal seams for a distance of only a few feet on either side ; far less marked than in the case of the mica-peridotite intrusives.

Like the latter intrusions, the dolerites have not been met with among the Supra-Panchet or the Durgapur beds.

The Salma dyke.

Of these dolerite intrusions, the Salma dyke—apparently so termed by Mr. Homfray, from its passing close to a shaft which he had sunk in Salma [1]—is the largest, and is well known to most of the mining community of the coal-field. Followed from the north, it is well-observed about 120 feet in thickness within the metamorphics a short distance west of Kanskuli and Chhotkar villages, keeping a steady S. 15° to 20° E. trend. Across the coalfield its direction varies slightly between Amdiha and Baliapur to the south of the Nonia stream, but further south it follows a very definite S. 18° to 20° E. line. It is prominently observed in the crossing of the Nonia *nala* where it is somewhat thicker than to the north, and continues, cropping out prominently over long distances, *via* Purana Chatti, Bara Pukhuriya colliery, and Damra, to the Damodar river near Boladanga. Across this tract of Gondwana outcrops the dyke is of the order of 150 to 160 feet in width. Among the Raniganj sandstones of the Damodar it forms a marked outcrop (*see* Plate 10, fig. 2). South of the river, it follows the same general direction through Sahebdanga village, but as the southern boundary of the field is approached it either dies out or is hidden beneath the superficial capping of soil and alluvium which covers a large part of these areas. Several minor vertical intrusions, of relatively small width, and of only local occurrence, exist as branches to this main intrusion, whilst in the northern side of the Damodar river a 12-foot dyke is observed, inclined at an angle of 60° within the sandstone outcrops. Another branch intrusion, only a few feet in thickness where it joins the main dyke in the northern bank of the Damodar, appears to increase considerably in width to the south and to continue south of the river, *via* Bhara village, in a direction parallel to the main Salma dyke. As in the case of the other intrusives of doleritic type, the adjoining strata have suffered little from the injection of these wide intrusions ; in the case of the Bara

[1] *Mem. Geol. Surv. Ind.*, III, Pt. 1, p. 141, (1861).

Pukhuriya mine the workings had extended up to within a short distance of the main dyke, and although the coal in the immediate vicinity was markedly crushed, the thermal effects of the intrusion were very slight.

The Narsamuda dyke.

To the south and west of Asansol, a well-marked dolerite dyke, about 50 feet thick, runs in a N. 42° W. direction *via* Narsamuda colliery. To the south-east, this dyke is possibly represented by the relatively thin intrusion, up to nine feet in thickness, which trends towards the Salma dyke just north of the Damodar river. North-west, it crops out at intervals within the Raniganj measures, but appears to die out a short distance north of Sitarampur.

The Sitarampur dyke.

Cropping out first near Sitarampur railway station, the Sitarampur dyke continues in approximately the same north-westerly direction as the Narsamuda intrusion, running *via* Lachhmanpur village, it enters the metamorphics near Debipur. Its thickness varies from 20 to 30 feet. An approximately parallel dyke traverses the Kulti-Kendua area.

The Charanpur dyke.

To the east of Asansol, another well-marked dolerite dyke-intrusion runs north-north-eastwards *via* Satpukhuriya village. This dyke appears to link up with the main Salma intrusion about half a mile north of the Grand Trunk road. It is possibly the continuation of this intrusion that traverses the old workings of the Charanpur mine. To the south of Satpukhuriya it is about 45 feet in width.

Physical characters.

In physical character, these rocks resemble the similar intrusions of the more western and southern Gondwara areas. Though sometimes almost unweathered, and massive in occurrence, they often exhibit prominent rectangular jointing, and have in some instances, particularly near the exterior of the intrusives, been markedly weathered externally in a concentric manner simulating 'trappoid' basalts. The unweathered specimens vary from black to dark grey, the weathered product being of a dark-green or brownish colour. The middle portions of certain of the large dykes are of a relatively coarse crystalline texture, though in the case of the smaller intrusions and of the outer portions of the larger, a medium to fine grain is observed.

Petrological characters.

Under the microscope, these rocks exhibit characteristics varying from normal dolerites to distinctly porphyritic types with and without olivine. Phenocrysts of zoned plagioclase, averaging basic labradorite in composition, occur in

an ophitic ground-mass of augite and labradorite together with ilmenite. Glassy crystallisation residues, in patches, fill up the interspaces.

Regarding the differentiation of these basic intrusions of Gondwana age from the suggested 'Dharwar' dolerites of the metamorphics to the north of the Adjai river, Mr. Auden notes the following points of dissimilarity :—

i. The common occurrence of interstitial glass, which has not been observed in the Dharwar dolerites.
ii. The felspar is usually turbid ; in the Dharwar types it is usually clear.
iii. The absence of a pronounced ophitic habit of the augites in the case of the Gondwana types.
iv. The absence of rhombic pyroxene in the Gondwana intrusions.

Temperature and fluidity of the magma.

It is obvious from the above-mentioned habit and metamorphic effects of these doleritic intrusions that, at the time of its injection, this basic magma was at a relatively low temperature, and that it was considerably more viscous than was the ultra-basic magma that resulted in the intrusive complex of mica-peridotite and lamprophyric dykes and sills. Causing, as they do, so little disturbance of the adjoining strata, and unrelated, apparently, to any lines of earlier movement or planes of weakness, it is difficult to conceive the exact *modus operandi* of these large magmatic injections of dolerite and basalt.

Influence on mining.

As a result of their limited occurrence, regular habit, and very slight detrimental effect on the coal seams, these dolerite intrusives present no great obstacles to mining in the Raniganj field. Except in those areas hidden by alluvium, the larger dykes can usually be accurately followed from the surface outcrops, and on account of their relatively vertical habit, their positions underground can, normally, be estimated with considerable accuracy. By reason of their extremely hard texture, and their occurrence as dykes of very considerable thickness within the areas already exploited, these intrusions are usually left as barriers within the mine and are rarely exposed within the workings. Their approach is often evidenced by a steady influx of water, which is in some cases impregnated with hydrated oxide of iron. As a result, few opportunities arose when it was possible to examine the dolerite-coal junction, and in the case of the Narsamuda mine, where the dyke had been penetrated, the workings were, unfortunately, closed at the time of the writer's visit,

was informed that the seam had suffered to within only a few feet of the edges of the intrusion.

No extrusive phase, in the form of lava flows, is encountered within the Raniganj field, either in the case of the basic or ultra-basic types. There is little doubt that at the time of injection of these dykes and sills the Lower Gondwana strata were deeply buried beneath Supra-Panchet and higher Gondwana beds. The dolerite intrusions, doubtless belonging to the similar group of basic rocks that have been met with in the more western coalfields and the adjoining crystalline areas of Bengal and Bihar & Orissa, have usually been correlated with the volcanic basalts of the Rajmahal hills, of an age not older than Lower Jurassic. This correlation was originally suggested by Dr. Blanford.[1] Recently, however, Dr. Fox[2] has pointed out that the Damodar valley dolerites may well belong to the Deccan trap period of vulcanicity, indicating a probable Middle Cretaceous age. That these dyke-intrusions of the Raniganj field were injected at a time subsequent to the faulting of the area is very definitely proved by the fact that they were unaffected by these displacements.

Age of the intrusions.

The ultra-basic, mica-peridotite and lamprophyric intrusives have, on the other hand, been shown conclusively to be very closely associated with these earth movements, though, at least in the great majority of cases, they also belong to a period subsequent to the displacements. This evidence alone suggests an age at least slightly older than the dolerites; but since this ultra-basic series is met with among the Panchet sedimentaries, and since the major faults of the field also affect the Supra-Panchet strata (of suggested Rhaetic age), it is obvious that they must belong to a period not older than the Lias. If we assume, therefore, that the dolerites are the dyke representatives of the Rajmahal lava-flows (also of Lower Jurassic age), it follows that the two series of intrusions were injected during a relatively short space of time, during the early part of the Jurassic period.

The evidence of the Raniganj area at least indicates a sequence of events in the following order:—

i. Earth-movements resulting in at least the major displacements of the Gondwana strata, followed very closely by
ii. the intrusion of the ultra-basic (mica-peridotite and lamprophyric) series, and
iii. the intrusion of the dolerites, definitely subsequent to the faulting.

[1] *Mem. Geol. Surv. Ind.*, III, Pt. 1, p. 149, (1816).
[2] *Op. cit.* LVI, pp. 113-114, (1930).

Further evidence regarding the relative ages of these two groups of intrusions is brought forward by Sir Thomas Holland,[1] in connection with the Giridih field. He states :—

'Where their (the basalts) junctions with the peridotites have been exposed and examined, it is seen that the latter rocks are displaced and cut through, proving the basalts to be distinctly younger than the mica-peridotites.'

Within the Jharia field, Dr. Fox[2] has recently found an exposure south of the railway cutting, east of Bamangora, where two faults are followed by later mica-trap dykes, and where both faults, and less clearly the mica-traps, appear to be cut by a dolerite dyke intrusion.

[1] *Rec. Geol. Surv. Ind.*, XXVIII, pp. 129-130, (1895).
[2] *Mem. Geol. Surv. Ind.*, LVI, p. 127, (1930).

CHAPTER XII.

GEOLOGY—*contd.*

Structure—Folds and Faults.

That the area of Gondwana rocks that now constitutes the Raniganj coalfield was subjected to a phase of relatively steady subsidence, extending over a very long epoch, during late Palæozoic and early Mesozoic times, is evidenced by the unbroken sequence of sediments of constant fresh-water, or estuarine type. There is, however, no reason to suggest that this area of gradual subsidence and accompanying sedimentation was limited by any tectonic structures—either rift-faults or pronounced folds—as has been previously suggested. On the contrary, there is little doubt that the present tract of Gondwanas, now included within the Raniganj coalfield, represents only a very small portion of the original area of Gondwana sedimentation, and owes its preservation to the fact that it has been subsequently faulted down within the Archæan land-mass and has thus been protected against the forces of erosion and atmospheric weathering. As has been previously observed, it is more than probable that this tract of Gondwana sedimentation continued, unbroken, in a general east to west line, across the ancient land-masses or Bengal and Bihar & Orissa, and westwards into Central India, and that the Damodar valley coalfields, as now represented, are merely isolated remnants of this once continuous Gondwana field. How far eastwards this area of sedimentation existed; whether it linked up with the present Gondwana tracts of the Darjeeling Himalayas and of Northern Burma; and if so, to what extent the deposits are preserved beneath the alluvium and laterite of Bengal, to the east of the present proved limits of the Raniganj field; are all questions which, in the present state of our knowledge, entail a very considerable degree of speculation. The latter problem is, however, one which, affecting as it does the question of the coal reserves of Bengal, is of great interest to the mining as well as to the geological world. Although, within the Raniganj field, there are indications of the thinning out of the Barakar measures in the north-eastern areas,

Faulting subsequent to the deposition of the Gondwanas.

there is no reason to suggest the absence of the Damudas including, in all probability, workable coal seams at least within the Raniganj beds, for a considerable distance to the east beneath the laterite and alluvial deposits, which exist beyond the present proved limits of the coalfield. That the alluvium thickens eastwards is more than probable. At the eastern extremity of the area included in the present survey, the general strike of the uppermost Raniganj measures is proved by borings to be in an east-north-easterly direction. This, combined with the evidence of the Kalipur bore-hole, might suggest the greater likelihood of workable coal seams being found in the more eastern alluvial tracts well to the north of the Grand Trunk road. Owing to the lack of available information, however, it is impossible to theorise on the geological structure of these hidden tracts of Gondwana strata, and the success of any explorations, which might in the future be carried out, must be largely a matter of chance. At the end of the present survey, the late Rao Bahadur Sethu Rama Rau extended his work to the south east beyond the limits of the attached geological map (Plates 19 and 20). In the area around Mulliahara (Malliarah), south of the Damodar river, he discovered outcrops of sandstones and shales comparable to those of the Raniganj measures. This tract was previously thought to be covered by alluvium, so that the discovery of these rocks *in situ* is of considerable interest, and should their correlation with the Upper Damudas of the Raniganj field prove correct, it should throw additional light on the problem of the extension of the Gondwanas beyond the present proved limits of the coalfield.

Extension of the Gondwanas to the east of the coalfield.

Outcrops *in situ* near Mulliahara.

There is little doubt that the Gondwana rocks of the major portion of the Raniganj field south of the Adjai river, owe their survival largely to the existence of the main complex boundary-fault which, limiting these deposits to the south and west, has caused them to subside within the harder Archæans to a depth varying up to at least 9,000 feet in the vicinity of Panchet hill. With the exception of certain tracts along the middle portion of the field, affected by strike- or oblique-faults, the northern limit of the coalfield is, in contrast to the southern, one of natural deposition, representing the uneven Archæan land-surface that existed in early Gond-

The southern boundary-fault.

The northern limits of the field.

wana times. This Archæan-Lower Gondwana junction has subsequently been further complicated by a number of cross-faults.

The main southern boundary-fault is by no means a single unbroken displacement, but rather a series of large strike-faults running *en echelon*. Commencing in the Archæans to the north-west, the displacement follows a S. 44° E. direction, bounding the Talchir and Barakar rocks just south of the Pusai stream. About half-a-mile north of the Grand Trunk road, its trend is locally affected by minor disturbances, south-east of which it continues very regularly in a S. 49° E. direction, bounding the Damuda rocks of the coalfield to within about three quarters of a mile north of the Damodar river. Further south-east, this Pusai-Patlabari boundary-fault appears to continue as a cross-fault within the Gondwana strata of the Kastabad-Deilya (Deoli) area. In the latter-named locality, the throw of this displacement within the lower Raniganj measures is of the order of 500 feet. Its extension further south-east cannot be traced with any great degree of certainty, and although it probably decreases in throw in this direction, there is a suggestion that it may be the continuation of this fault that appreciably affects the upper Raniganj strata of the Machkanda Jor, one mile north of Murulia.

The Pusai-Patlabari fault.

South of the Damodar river, its place is taken by a second main boundary-fault, the Panchet hill - Jemua dislocation. This fault, running along the southern slopes of Panchet, Gorangi, and Biharinath hills, follows a general east-south-easterly direction as far as the hill of Gorangi, east of which, to beyond Jemua, its trend varies from due east to east-inclined south. Within this Panchet hill-Jemua tract, Gondwana horizons, varying from Supra-Panchet down to upper Raniganj, abut against the Archæans. To the east of the longitude of Raniganj, the fault is hidden beneath alluvium. At several points this main dislocation is interrupted by a number of relatively small cross-faults.

The Panchet hill - Jemua fault.

Regarding the Archæan-Gondwana junction of the Kastabad-Baghmara area, between these two main dislocations, it has been previously mentioned that there is good reason to believe that the boundary in the Damodar river is one of natural deposition, though further south, in the Baghmara area, a cross-fault doubtless limits the western extension of the Middle and Upper Damuda rocks.

The Kastabad-Baghmara boundary.

Tectonics of the Gondwanas near the boundary-faults.

As has been previously observed, the general inclination of the Gondwana strata of the Raniganj field is towards, or slightly oblique to, these main southern and south-western dislocations. As the faults are approached, however, the effects of these immense subsidences are evidenced; the older strata are in many cases brought up against the faults in the form of a sharp synclinal and in the immediate vicinity of the fracture dip at steep angles to the north-east and north. Variations in the intensity of these accompanying disturbances have further complicated these synclinal tracts, breaking them up into an alternating succession of small domes and basins, in some instances truncated to the south-west and south by the displacements. In the extreme north-west of the field, to the south of the Pusai *nala*, a narrow band of crushed Talchir outcrops is brought up in a sharp, probably broken synclinal, to the south-west of the Pusai stream. Further south-east, the Barakar rocks swing round parallel to the main dislocation and, to the south of the Grand Trunk road, occur as an alternation of synclinal basins and anticlinal domes. These structures include the Shampur and Chatabar basins and the Kudia syncline. Adjoining the Panchet hill - Jemua fault, similar structures are observed, and have been studied in detail by Mr. Sethu Rama Rau.[1] In these instances, the alternating domes and shallow synclinal basins appear less complete, their southern limbs being truncated by the main displacement. Within the shallow truncated basins of Panchet, Gorangi, and Biharinath hills, the newer rocks, of Supra-Panchet and Panchet age, abut against the Archæans, whilst in the intermediate areas the Raniganj measures crop out, forming a prominent dome in the vicinity of Jemua. Immediately adjoining these faults, the Gondwanas are considerably shattered, the softer coal and shale bands are attenuated, and the more massive sandstones often indurated and silicified to form semi-quartzites. In the case of the Pusai-Patlabari displacement, such induration and silicification is well-observed in the Barakar grits and sandstones in the vicinity of Chatabar village. To the west of the village, an elongated hillock runs parallel to the fault. The north east side of this small ridge is composed of Barakar sandstones, dipping steeply to the north-east. These pass inside the ridge into a brecciated silicified sandstone zone, intersected by irregular veins of white quartz. As we approach the Archæans,

Quartz veins adjoining the boundary-fault.

[1] **Proc. Sixteenth Ind. Sci. Congn. Abst.,** ***Asiat. Soc. Beng.,*** **p. 281, 1929).**

the quartz veins increase and on the south-western slopes the rocks are definitely of hard, shattered, semi-quartzitic type stained with yellow to reddish tints. The micaceous hornblende-gneisses of the Archæans crop out just south-west of this silicified zone, striking almost vertically in an east-south-easterly to south-easterly direction, oblique to the displacement. A similar hillock of crushed sandstone and semi-quartzite is observed a short distance to the south-east. In the approach to Patlabari, a narrow band of crushed Talchir strata crops out against the boundary-fault, in the southern steep limb of the Kudia synclinal.

In the case of the Panchet hill - Jemua dislocation, similar silicification and brecciation is observed in the massive Supra-Panchet and Upper Panchet sandstones of the hills, which adjoin the southern boundary of the coalfield, though in the intermediate areas, such silicification does not appear to accompany the local shattering and steep inclination of the Gondwanas. Mention has already been made of the occurrence of mica-peridotite dyke intrusions within the Barakar measures immediately adjoining the Pusai-Patlabari fault.

The Adjai river fault.

In the extreme north-eastern part of the coalfield, the large oblique strike-fault of the Adjai river with a downthrow to the north-east, has, in a manner similar to the above-described southern boundary-fault, affected the preservation of the Trans-Adjai strip of Damuda sediments. With the exception of local faults, and evidence of shearing in the Karabad area, the north-eastern junction of the Archæans and Lower Damudas of this portion of the coalfield, is again a line of natural deposition. Following a somewhat similar east-south-easterly to south-easterly trend, the fault is largely hidden beneath the sand and alluvium of the river. It is, however, exposed in the right bank of the river near the pumping station, half a mile north-east of Amulia, the Barakar sandstones on the north-eastern side of the fault being considerably crushed and indurated. To the south-east, in the Birkulti-Bhuri area, Mr. Auden suggests that this fault passes, at least to some extent, into a monoclinal fold. Across this south-eastern area, the displacement continues as an oblique cross-fault within the Damudas, and, with a downthrow of several hundred feet to the north-east, brings the Raniganj measures of the Chhatrishganda-Kendra area against Ironstone Shales of the Bhuri locality. The exact continuation of this fault to the east, within the Dalurband-Purushottampur tract, is uncertain, though it is

probable that, like the Pusai-Patlabari displacement, its throw decreases in this direction.

Faults near the northern boundary.

In addition to these main dislocations, are a number of cross-faults, some of very considerable throw, others of only minor consequence, which complicate the northern boundary of the coalfield and in some cases continue southwards for a great distance within the higher Gondwana strata. In other instances, however, these faults appear to be confined to the Talchir and Lower Damuda outcrops of the northern part of the coalfield, and such phenomena led Dr. Blanford to suggest that some of these displacements might well be of Lower Damuda or even Talchir age. Unfortunately, the Barakar-Ironstone Shale boundary is so badly exposed that it is impossible to trace the effect of many of these displacements up into these Middle Damuda measures. Of these northern oblique cross-faults the following are the most important, the Jeruwadih-Ghagra fault, the Boldih fault and the Rajpura-Kalimati fault, to the west of the Barakar river; the complex dislocations of the Barakar river area; the Salanpur trough faults, the Itapora-Panuria fault and the Madanpur-Sarshatali fault, between the Barakar and Adjai rivers. In the case of the Boldih fault the fracture is observed, to the east of Boldih village, to be inclined at the low angle of 35° to 40°, and veins of white cellular quartz intersect the Talchir sandstones in the vicinity of the village. In the instance of the Salanpur, Panuria and Sarshatali faults the strata swing round markedly, almost parallel to the dislocation, so that the local structures include a succession of fractured monoclines following along the lines of the faults, with synclinals, pitching steeply southwards, in the adjoining areas.

Other large displacements.

In addition to the above-described displacements, a glance at the geological map (Plates 19 and 20) shows the existence of a number of displacements of variable throw and direction, traversing the Gondwana rocks of the field. These disturbances include, in the western and middle portions of the field to the north of the Damodar river, the complex faults of the Barakar river - Kumhardubhi area; the Begunia-Petana strike-fault of from 400 to 600 feet in throw, separating the Barakar and Ironstone Shale beds; the Debipur-Lakrajoria strike-fault, which limits the Barakar and Talchir beds to the north of Damagaria and Bahira; the cross-fault separating the Lalbazar

and Bahira areas; the strike-faults of the Paharpur area, which repeat the lower Barakar measures; the strike- and dip-faults of the Jayramdanga-Barabani area; the large cross-fault separating the Charanpur and Banksimila collieries and continuing south-westwards *via* Banbishnupur (Bonbistopur) to beyond Mohishila (Muslia); the cross-faults of the Ghoshik (Ghusick)-Chelad area; and the succession of large cross-faults of the Jamuria-Sekpur area, which, at least in the case of the Jamuria dislocation, probably continue southwards to Siarsol and Raniganj. In the eastern parts of the coalfield a number of strike- and dip-faults complicate the Raniganj outcrops, and there is every reason to conclude that equally large disturbances would be met with among the Gondwana strata beneath the laterite and alluvium to the east of the present proved limits of the coalfield. To the south of the Damodar river, north of Gorangi and Biharinath hills, equally complex dislocations affect the Raniganj and Panchet strata.

In general, these displacements follow a very direct trend, though they often vary considerably in throw and die out within the coalfield. They all appear to be faults of the normal type with a hade varying from nearly vertical to as low as 45°. An instance of a fault with such an appreciable hade was noted in Messrs. Burn & Co.'s Raniganj mine and again at Deoli colliery. In some cases, these strike and dip displacements appear to cross each other with only slight deflection. The faults are accompanied by local marked shattering of the strata, and, as previously observed, in some instances by the intrusion of dykes of ultra-basic types.

Hade of faults.

It will be gathered from the above description that the major complications of the Raniganj field are the result of tectonic displacements of the normal type resulting from the accommodation of tensional stresses. In the case of the larger displacements, local folding has accompanied these dislocations.

In addition to these structures, however, there is, along the north-eastern boundary of the coalfield, some evidence of compressional forces, causing the slight overthrusting and local induration of the basal Barakar measures. Evidence of such overthrusting is observed in these beds just north of the railway-line of the Churulia area, and again more clearly in the vicinity of Karabad in the Trans-Adjai area. In the former locality the basal Barakar sandstones,

Overthrusting along the north-eastern boundary.

including a few pebbles of white quartzite as in the undisturbed tract to the north-west, are somewhat silicified and indurated, and are intersected by occasional thin lenticular-shaped veins of white quartz running roughly parallel to the bedding of the sandstones. In the railway-cutting of Karabad, the Barakar-Archæan junction is well-exposed. At the north-western end of the cutting this junction is definitely one of normal deposition, almost conformable to the quartz-mica-schists of this area. Further south-east, however, immediately behind the colliery, similar metamorphic rocks, immediately underlying the Barakars, include several thin lenticular-shaped bands of indurated grey shale and fine sandstone, running approximately parallel to the foliation of the gneisses, and strongly suggesting *lit-par-lit* injections. It is possible, therefore, that some of the strike-faults, which cut out certain of the lower Barakar measures of this locality, may be found to be in the nature of reversed displacements or inclined overthrusts.

Age of faults and folds.

Regarding the exact age of the above-described faults and folds of the Raniganj coalfield, it is, as in the case of the intrusions of the field, impossible to dogmatise with any degree of certainty. Evidence has already been brought forward proving that these earth-movements took place before the phase of dolerite intrusion, and, in at least the majority of instances, prior to the injection of the ultra-basic rocks. It is possible that minor faulting and folding commenced in early Gondwana times; on the other hand it is certain that the major displacements, affecting as they do the Lower Gondwanas and Supra-Panchets alike, took place at a later date, probably during Jurassic times.

PART II.

CHAPTER XIII.

DETAILED GEOLOGY AND CORRELATION OF THE COAL-BEARING DAMUDAS.

General Observations.

In dealing with a series of estuarine, deltaic, and lacustrine sediments such as are included in the Lower Gondwanas of the Damodar valley coalfields, lateral variations in detail are to be expected, even when comparing closely connected sections. In view of the fact, however, that the Gondwana areas of the various coalfields—now separated from each other by relatively wide tracts of metamorphic rocks—formed, at the time of their deposition, one connected area of sedimentation, it would not be surprising to find a marked general resemblance between the various sedimentary stages not only of widely-separated portions of the same coalfield, but also of adjoining fields. Although separated by a metamorphic tract to the extent of about 14 miles, a general correlation, between the principal stages of the Damuda sediments of the Raniganj and Jharia coalfields, might therefore be expected. The latter area has been recently surveyed (on a scale of four inches to one mile) and described in detail by Dr. Fox, and from a comparison of notes the following correlation of the main stages of Damuda sediments, represented in the Jharia and in the western part of the Raniganj field, has resulted.

General correlation with the Jharia field.

Within the Jharia coalfield no rocks younger than the Raniganj measures are represented. As in the case of the Raniganj area, the Talchirs are well-exposed adjoining the metamorphics of the northern boundary of the Jharia field and bear a marked general resemblance to those of the former area and to the more western outcrops of the Damuda valley. In the Raniganj coalfield alone, occurs the sequence of grey and black shales with numerous ironstone bands, of sufficient individuality and thickness to justify their being grouped as a separate series of Middle Damuda sediments—the Ironstone Shales. The alternative name—Kulti shales

Table 2.

JHARIA COALFIELD.		RANIGANJ COALFIELD.	
Classification adopted by Dr. C. S. Fox.	Stages.	Stages.	Classification adopted by the writer.
Raniganj series. (1,840 ft.)	Lohpiti sandstones (200 ft.)	Kumarpur sandstones (300 ft.)	Raniganj series. (3,400 ft.)
	Telmucha coal measures (300 ft.)	Nituria coal measures.	
	Jamdiha sandstones.	Hijuli sandstones.	
	Muruliddih coal measures.	Sitarampur coal measures.	
Barren measures. (2,080 ft.)	Mahuda sandstones (600 ft.)	Ethora sandstones (600 ft.)	
	Hariharpur carbonaceous shales (200 ft.).	Ironstone Shales (Kulti shales).	Ironstone Shales (1,200 ft.).
	Petia sandstones (200 ft.)	Begunia sandstones (100 ft.)	Barakar series. (2,100 ft.)
	Shibbabudih shales.	Begunia shales.	
Barakar series. (2,000 ft.)	No. XVIII seam. ?	— Begunia seam.	
	Middle & Lower Barakar measures.	Middle & Lower Barakar measures.	

—has been suggested by Dr. Fox for these beds. In the coalfields to the west, these Ironstone Shale sediments appear to have thinned considerably (as noted in the foregoing Table 2) and Dr. Fox suggests that they are represented in the Jharia area by only 200 feet of argillaceous strata. Such a pronounced variation in the thickness of these sediments is not surprising, considering the probable lacustrine conditions that prevailed during that epoch. It has been previously noted that the Damudas represent a group of sediments relatively conformable throughout. It therefore follows that, in dividing these beds into the various series for the purpose

of geological mapping, any such classification must, in the absence of well-marked fossil-zones of distinct identity, be based on the lithology of the sediments. In the case of the Raniganj field, the presence of the above-mentioned thick zone of shales with ironstones, separating a lower and an upper coal-bearing series, obviates the division, so that in the recent re-survey this classification, originally adopted by Dr. Blanford, and well known to all who are interested in the geology of the coalfield, was found to be a very satisfactory one. In the case of the Jharia field, however, owing to the absence of any marked 'Ironstone Shale' horizon of sufficient thickness and individuality to justify its classification as a separate series in field-mapping, and with the object of emphasising the economic aspects of the geology, Dr. Fox has adopted a slightly different classification. He has divided the Damuda rocks of that area into an upper and a lower coal-bearing series, and has included in an intermediate group—termed by him the 'Barren measures'—not only the relatively thin shale beds, which are regarded as equivalent to the Ironstone Shales of the Raniganj field, but also those barren strata homotaxial with the uppermost Barakar and basal Raniganj horizons, which occur below and above the Ironstone Shales. The upper limit of the 'Barren measures' of the Jharia field is, therefore, represented by the base of the lowest main coal seam of the Upper coal measures (? = the Sanctoria seam of the Raniganj field), whilst the base of the Barren measures is drawn at the top of the uppermost main seam of the Lower coal measures (? = the Begunia seam of the Raniganj field).

Sub-division of Damudas in Raniganj and Jharia fields.

Within the Jharia field the Barakar measures, though they show a strong general resemblance to those of the Raniganj area, include a much greater number of coal seams of economic worth, whilst in the Raniganj field the seams of the Raniganj series are of far greater value than those of the Jharia area. Bearing in mind these marked differences, it is, of course, impossible to attempt to continue the above correlation in greater detail, with any degree of certainty.

Within the precincts of the Raniganj field, however, it has been found possible to recognise the various coal measure horizons throughout the greater part of the area, although in a few instances doubt still remains regarding the exact correlation of the individual coal seams.

The three tables (Plates 16 to 18) giving vertical sections of the measures at intervals from west to east across the length of the coalfield, exemplify the details of the sequence within the different localities and illustrate the conclusions reached regarding the equivalence of the coal seams. In arriving at such a correlation of the coal seams of the Raniganj field, the following criteria have been considered:—

Basis of correlation.

1. The sequence and vertical intervals between the seams.
2. The lithological characters, thickness, and sequence of the strata intervening between the seams.
3. The thickness of the seams.
4. The character of the seams; external character of the coal, chemical composition, presence of shale or stone bands.

Regarding these various criteria, the following observations may be recorded:—

1. *The sequence and vertical intervals between the seams.*

There is evidence that the strata of the Barakar series represent a group of sediments liable to greater variation laterally than is the case with those of the Raniganj measures. Even in these lower measures, however, there is considerable uniformity in the *general* sequence and vertical thicknesses of the strata intervening between certain of the main coal seams, and, in most cases, such variations as do occur are relatively gradual, so that in comparing sections of equivalent horizons not very distant from one another good evidence regarding the continuation of the individual beds can usually be obtained. Instances of rapid lateral variation in the thicknesses of these intervening strata are, however, met with. Within the Barakars, there is a considerable change in the beds below the Damagaria-Salanpur 'A' seam when traced to the east into the Gourangdi-Churulia and the Trans-Adjai tracts, a change coincident with the dying-out of the basal beds of this series. Again, the thickness of strata separating the Salanpur 'A' and 'C' seams is much greater than that intervening between their presumed equivalents in the north-eastern parts of the field. Within the middle Barakar measures, the variation which occurs in the thickness of the bands that divide the Laikdih seam into several zones is striking, even in the case of the closely situated areas of Lalbazar and Bahira. Again, the upper Barakar beds, representing the horizons between the Laikdih and Begunia seams, are of the order of 600 feet in thickness near the

Barakar measures.

Barakar river (including the Ramnagar seam as the topmost of the Laikdih group), whilst in the Kantapahari-Jamgram tract these beds appear to have decreased considerably in thickness. In general, therefore, in the case of the Barakar series, a very considerable decrease in the thicknesses of the strata intervening between the coal seams is noticeable when followed eastwards from the Barakar river over relatively wide areas.

Raniganj measures.

In the case of the beds of the Raniganj series, considerable uniformity prevails, though several instances of marked lateral variation are evidenced. For example, the basal barren measures beneath the Gangutiya and Taltor seams again show a marked change from west to east. East of the Barakar river, in the middle portion of the field, these unproductive beds must be from 600 to 700 feet thick, but further east, in the Chichuria-Daluka area, they appear to be less than 400 feet, and it is suggested that they die out almost entirely in the Ramnagar-Kendra tract. In the case of the middle Raniganj measures in the eastern half of the field, lateral variation in the thickness of these intervening beds is again more noticeable. For instance, between the Poriarpur-Satgram seam and the Koiti-Poniati group of the area lying between the longitudes of Barabani and Jamuria, there is a considerable thickness of strata—about 800 feet; whilst to the east of the faulted tract of Ikra, the equivalent beds of the Tapasi (Toposi)-Dhasul area are very considerably thinner. Further east, these strata remain fairly constant in thickness. Within the extreme eastern parts of the field, the greatest change is the almost complete dying-out of the strata separating the Lower Kajora and the Sonachora seams, the seams running together to form the thick Jambad seam.

2. *The lithological characters, thickness and sequence of the strata intervening between the seams.*

As is to be expected in such a group of estuarine or river deposits, lateral changes in the character of these intervening strata are also exemplified. On the other hand, in many cases, bearing in mind the nature of these sediments, the character and thickness of the various beds are often extremely uniform over wide areas. In the case of the Barakar measures, the basal pebble-bearing sand-

Barakar measures.

stones, though they thin considerably to the east, are yet recognisable in the majority of

sections, and afford a valuable horizon for correlation purposes. Above the Damagaria seam and its equivalent coal-shales of the eastern parts of the coalfield, massive grits including several seams of good quality fireclay, persist throughout the field. Higher in these measures, massive grits with some quartzite pebbles appear to persist over considerable distances, and, were more complete bore-hole sections of the middle and eastern Barakar outcrops available, such horizons would, no doubt, prove useful in detailed correlation. As an example of a rapid change in the lithology of these strata, the instance of the uppermost Barakar beds above the Begunia seam might be cited. These strata include massive sandstones just east of the Barakar river, but vary into sandy shales to the east.

Raniganj measures.

Within the Raniganj measures, the general character of the sediments often continues over wide areas. Beneath the Sanctoria seam of the western part of the field, the fine- to medium-textured sandstones, including grains of red felspar, and associated with sideritic sandstone bands weathering into lenticular-shaped outcrops, are traceable eastwards across the middle portions of the field. In the upper Raniganj beds one might quote the persistent characters of the strata above and below the Ghusick-Siarsol-Upper Kajora seam. The Ghusick seam, at Kalipahari, is overlain by a considerable thickness of shales and sandy shales, which continue at this horizon across the eastern part of the coalfield. Above these beds is a series of alternating sandstones and shales with thin coal seams, equally constant. Below the above-mentioned coal seam, notably in the Siarsol area and still further east, massive sandstones prevail down to the Raniganj-Lower Kajora seam. They vary in thickness from 150 to 220 feet, though in lithology they are very uniform.

3. *The thickness of the seams.*

Barakar measures.

Remarks similar to the above might be quoted regarding the coal seams. Within the Barakar measures, the changes in thickness are more pronounced, and often rapid, and, speaking generally, the seams are found to vary considerably over relatively wide areas. These changes are, however, usually general in one direction; there is, in fact, an almost general decrease in the thickness of the coal seams as the coalfield is traversed from west to east. Sufficiently deep borings

are not available to suggest marked lateral changes to the dip, though some variation must be expected. The lowest main coal seam—the Pusai seam—thins from about 25 feet in the extreme west to only a few feet before the Barakar river is reached. The Damagaria seam, of a total thickness of about 100 feet just east of the Barakar river, thins gradually eastwards, as do also the coal seams of the Laikdih group, and the Begunia seam. One important exception to this rule is the Salanpur 'C' seam, which, of the order of 18 feet thick at Salanpur, is apparently represented by the 20-foot Gourangdi-Jamgram seam of the Panuria area. Further east, in the Churulia area, this seam appears to have increased to over 30 feet thick, and is met with in the Pariarpur tract of the Trans-Adjai portion of the coalfield, as much as 40 feet in total thickness. Further south-east, however, this coal seam also thins considerably.

It is obvious, therefore, at least in the case of the Barakars, that no great reliance can be placed on the total thickness of the individual seams for a purpose of correlation over wide areas.

Raniganj measures.

In the case of the Raniganj beds, there is a far greater uniformity in the thickness of the coal seams over wide areas, though even here, also, fairly rapid changes are noted in some instances. Gradual changes take place in the thickness of the majority of the coal seams, but these changes may vary in different areas, no persistent decrease or increase in one direction being noticeable as was the case in the majority of the seams of the Barakar series. Within two tracts in particular, variation takes place fairly rapidly in a number of the coal seams; in the first instance, within the Chinchuria-Dhadka-Kalipahari area, and in the second instance, within the area around Tapasi and Sekpur. In the former tract, the lower and the upper seams of the Raniganj measures undergo considerable variation in thickness, the middle seam—the Manoharbahal-Rana-Pariarpur seam —being fairly constant. In the more eastern areas, the upper seams remain constant and the middle and lower seams of the group show marked lateral changes. Still further east the most important variations are, firstly, the dying-out of the lowest coal seams of the measures; secondly, the splitting up of the Chora-Purushottampur seam; and thirdly, the running together of the Lower Kajora and Sonachora seams, to form the Jambad seam.

4. *The character of the seams.*

The characters of the individual coal seams of the Raniganj field, although showing considerable variation, are very useful guides in arriving at a correlation, both in the case of local and widely distant areas. With regard to the seams of the Barakar measures, with the exception of the Salanpur 'C'-Gourangdi-Kasta seam, there is a general deterioration in the quality of these coal seams as we follow them eastwards from the Damagaria-Bahira area. Generally speaking, the thick seams are of better quality in their lower portions and become very shaly in the upper parts, indicating a rapid change in deposition from the sandstone and shale sediments below up into fairly pure coal-substance, and a much more gradual change upwards into the overlying unproductive measures. The coals of the Barakars are, on the whole, low in moisture and comparatively low in volatiles, with a high percentage of fixed carbon. These characters are more marked in the basal seams, the moisture and volatiles increasing in a fairly regular sequence as we rise in the series. In the case of the lowest Barakar seams—Salanpur 'A' to 'C'—the coal is largely of a dull nature, vitrain (bright coal) being present only in very thin bands. In the case of the middle and upper seams—those of the Laikdih group and the Begunia seam—there is a distinct increase in the proportion of vitrain, and certain horizons exhibit a marked 'ball-structure'.

Barakar measures.

Referring to the coal seams of the Raniganj measures, the percentage of moisture and volatiles is usually high, many of the coals being good gas coals, yielding a soft coke of porous texture. The coals include a considerable proportion of vitrain and, in the case of the Dishergarh seam, fusain is also prominent. Many of these Raniganj coals, when in the form of slack, are very liable to spontaneous combustion.

Raniganj measures.

The character of the roof and floor of the various seams is in some cases important in correlation, though, unless a detailed accurate account is available from a bore-hole or shaft section, it is often impossible to obtain this information.

The presence and distribution of shale and sandstone bands within the various seams play an important part in any correlation, for although the bands may vary considerably over wide areas, they are often very constant in occurrence (as in the case of the

Bands within the coal seams.

upper Raniganj seams of the middle and eastern parts of the field), as is also the quality of the coal of the various portions of these seams.

It is indicated from the above that one cannot depend on one solitary resemblance for the purpose of recognising an equivalent coal seam. In certain cases, where accurate sections are not available, one has to rely largely on the thickness of the strata comprising the coal-bearing sequence, the conclusions in such cases being sometimes open to question. In other instances, the cumulative evidence leaves little room for doubt, especially when borne out by the geological structure of the area in question.

CHAPTER XIV.

DETAILED GEOLOGY & CORRELATION OF THE COAL-BEARING DAMUDAS—*contd.*

Barakar Measures.

The Barakar coal measures of the Raniganj field, including those tracts now hidden by alluvium, cover a total area of nearly 66 square miles. To the west of the Barakar river, very fine sections of the upper and middle portions of this series are exposed in the Kudia tributary, while in the Pusai *nala* of the north-western corner of the field, the lowest horizons can be equally well observed. East of these areas, few complete sections of the succession are exposed over any great distance, so that, in arriving at a detailed description of the beds, one has to rely to a large extent on the records of colliery-workings and bore-holes. Large tracts of these middle and eastern areas are hidden by a soil-capping of varying thickness, and in the extreme east, in the Trans-Adjai region, the lowest Barakar horizons alone are exposed from among the thick alluvial deposits that border the Adjai river.

Outcrops of Barakars.

Unfortunately, on account of the dying-out of many of the Barakar seams to the east and of the paucity of outcrops of those coal seams that do persist, combined with a lack of railway communications rendering the areas less attractive to colliery enterprise, large portions of the area of Barakar outcrops to the north of Sitarampur and Asansol have remained untouched during the progress of colliery development, so that, except for the limited exposures of the harder sandstone and grit beds, little detailed information can be obtained regarding the middle and upper Barakar stages. The lower measures, however, including as they do intercalations of thick massive grits and sandstones, and the easterly continuation of the thick Salanpur 'A' seam, crop out fairly consistently throughout the length of the field.

Division into areas.

In describing the Barakar rocks of the Raniganj field, it is convenient to divide the area into the following five tracts. These include :—

I. Area west of the Barakar river.

II. Ramnagar-Itapora area.

III. Gourangdi-Churulia area.
IV. Trans-Adjai area.
V. Area adjoining the Damodar river.

Though, during early Gondwana times, these five tracts doubtless formed one continuous region of sedimentation, subsequent earth movements, followed by erosion, have now rendered them structurally or topographically distinct, to a greater or less degree.

From Tables 3 to 5, it will be observed that the Barakar measures of these various tracts, excluding the Damodar river area, have been sub-divided into seven stages. In spite of a considerable lateral variation in the individual beds and the absence of the uppermost Barakar measures along certain tracts, these various stages can be followed with sufficient conviction, at least in the western half of the field, to justify this classification. Local names have been applied to these subdivisions; these indicate the locality around which the beds crop out at the surface, or underlie the superficial covering of soil and alluvium in the case of the more eastern areas.

Division into stages.

I.—Area west of the Barakar river.

Resting with no obvious unconformity on the Talchir series, the Barakar rocks crop out over the southern part of the Gondwana area to the west of the Barakar river. This extreme western portion of the coalfield includes the Pusai, Shampur, Chatabar, Patlabari, Lakhdih, and Kalimati colliery areas. Along the southern boundary, these rocks are truncated by the main boundary-fault of the coalfield. As previously mentioned, the general inclination of the lower horizons of these Barakar measures, exposed mainly across the northern and middle portions of this area, varies from south to south-west at gentle to moderate angles, but as the southern boundary fault is approached the higher Barakar rocks are thrown into a series of three synclinals or synclinal basins, and older beds of various horizons again crop out against the faulted metamorphics in the southern limbs of these synclinal structures. These three structures include the Shampur and Chatabar basins and the Kudia syncline.

General structure.

Excluding the main boundary fault, the above-mentioned Barakar areas are almost devoid of displacements. East of the longitude of the eastern end of the Kudia syncline, that is to say, between the Agiarkund-Dahibari area and the Barakar river, cross-

faults of very considerable throw complicate the Barakar measures. It has been found convenient to sub-divide this tract of the Barakar rocks, west of the Barakar river, into the following four areas :—

1. The Pusai-Shampur area.
2. The Birsinghpur-Mugma-Chatabar area.
3. The Kapasara-Garphalbari-Dahibari area.
4. The Kalimati-Kumhardubhi-Chanch area.

The stages corresponding to these various areas are given below (*see* page 120, Table 3).

The detailed lithology and structure of these various tracts are as follows :—

PUSAI-SHAMPUR AREA.

Structure.

The inclination of the Barakar measures, along the strike of which the Pusai stream flows as far east as Khusori, varies from south-west to due south at gentle to moderate angles. Except in the near vicinity of the main boundary-fault, this steady dip continues within the higher Barakar rocks across the Grand Trunk road to the Kudia *nala*, north of Shampur. Within and to the south of this latter stream-section, the upper and middle Barakar measures crop out in the form of an oval-shaped basin, with its longer axis running north-west to south-east, parallel to the boundary-fault. Entering from the metamorphics of the west, the Kudia stream meanders across these Barakar measures of the northern half of this Shampur basin and exposes a fairly continuous succession throughout a large portion of its length, traversing the same middle Barakar horizons in at least two sections, in the north-western and in the eastern parts of the basin.

The Barakar rocks of the Pusai-Shampur area may be conveniently divided into the following stages :—

		Ft.	
vii.	Upper Shampur coal measures	300	(approx.)
vi.	Middle Shampur coal measures	200	,,
v.	Lower Shampur coal measures	250	,,
iv.	Kudia shale and sandstone stage . . .	200	,,
iii.	Nirsa grits	450	,,
ii.	Kanauri coal measures	300	,,
i.	Pusai conglomerates with coal seam . . .	350	,,
	TOTAL .	2,050	,,

TABLE 3.—*West of the Barakar river.* (4-inch sheets Nos. 1, 2, 4 & 5.)

STAGE.	PUSAI-SHAMPUR AREA.	BIRSINGHPUR-MUGMA-CHATABAR AREA.	KAPASARA-GARPHALBARI-DAHIBARI AREA.	KALIMATI-KUMHARDUBHI-CHANCH AREA.
vii	Upper Shampur coal measures .	Absent	Absent	Chanch coal measures.
vi	Middle Shampur coal measures .	(Upper portion absent) . . Upper Chatabar coal measures.	Absent	Laikdih shales and sandstones.
v	Lower Shampur coal measures .	Lower Chatabar coal measures .	Absent	Laikdih-Patlabari coal measures.
iv	Kudia shales and sandstone .	Kudia shales	Gopinathpur shales . . .	Kalian Chak shales and sandstones.
iii	Nirsa grits	Mugma grits	Garphalbari-Dahibari grits .	Chirkunda grits, with coal seams.
ii	Kanauri coal measures . .	Birsinghpur coal measures . .	(*b*) Bindabanpur coal measures . (*a*) Kapasara coal measures .	(*b*) Siulibari coal measures. (*a*) Kalimati coal measures.
i	Pusai conglomerates with coal seam.	Sasangberia conglomerates .	Kapasara conglomerates . .	Rajpura conglomerates.

— — — — TALCHIRS — — — —

i. Pusai conglomerates, with coal seam.

Where best exposed, to the west of Kosumkanali, these basal Barakar sediments include the following succession in descending order:—

The western Pusai area.

Massive, white and grey felspathic, coarse and medium-textured sandstones fairly soft, and including numerous well-rounded boulders, largely of quartzite, varying up to nine inches in diameter; 250 feet (approx.).

Pusai *coal* seam; coal and shaly coal with shale bands; 30 feet (approx.).

Hard, bedded, somewhat ferruginous sandstones, with softer grey and yellow-grey types, including two seams of dark grey carbonaceous shale; 50 to 60 feet (approx.).

(These beds pass below into yellow-green, fine- to medium-textured sandstones, with greyish and greenish shales, of Talchir type.)

A cross-fault, running east-north-east to west-south-west, and with a downthrow to the south-east, intersects these lower Barakar and upper Talchir rocks in the vicinity of Chulhapora colliery. To the north-west of this cross-fault, for a distance of about $1\frac{1}{4}$ miles, the rocks of the Pusai conglomerate stage are exposed as a narrow strip, of a maximum width of 575 yards. They appear to form a shallow syncline, truncated to the south-west by the main boundary fault. Against the metamorphics on the northern side of this main fault, a narrow strip of Talchir sediments is exposed, dipping steeply to the north-east, whilst adjoining these Talchir strata the boulder-bearing Pusai sandstones dip at much gentler angles to the north-east, and although no actual dislocation is exposed among the discontinuous outcrops of this locality, the incompleteness of this lithological sequence indicates the presence of a second fault, in the nature of a step-fault, running parallel to the main boundary-fault, and separating these two sedimentary groups. Such would explain the absence of the Pusai seam and the upper Talchir strata in the south-western limb of this synclinal.

To the west of Chulhapora colliery, the Pusai seam crops out in the bed of the Pusai and Sonbad *nalas*, dipping south-west at about 20°. Portions of the seam have been worked in the past at the outcrop and for a short distance beneath the pebbly sandstones of the south-western bank of the Pusai, both at Chulhapora and Baraigarha collieries. The coal, at least at its outcrop, is, however, of poor quality and these surface workings are now closed. Further west, the Pusai seam recrosses the *nala* near Chapapur colliery, dipping S. 15° W.

The Pusai seam.

at 20°. An abandoned quarry occurs close to the stream-bed, but the seam is now worked on a small scale from inclines to the south. The bottom portion of the seam is, apparently, of the better quality. The section of the seam at this colliery is given as follows :-

	Ft.	in.
(Earth and stone, eight feet)		
Shaly *coal* and shale	2	0
Band	2	3
Coal	9	0
Band	2	0
Coal (worked)	7	0
TOTAL	22	3

Dyke intrusions.

The sedimentary strata of this north-western area are intersected by a number of mica-peridotite dykes, usually only a few feet in thickness. These intrusions have caused the local coking of the Pusai seam. One particularly well-exposed example is the 4-foot dyke running west 15° south across the Sonbad *nala*, 200 yards west of its junction with the Pusai. (*See* Plate 7.)

To the east of the Chulhapora cross-fault, the main boundary-fault continues in a south-south-easterly direction following obliquely to the dip of the strata, so that the Barakar measures are exposed over a much wider area, and higher horizons come in to the south. Adjoining this main fault, just south of the above-mentioned cross-fault, a small patch of steeply-dipping Talchir sediments again crops out. These beds, however, die out within a short distance, and further south-east, up to and beyond the Chatabar area, various horizons of the Barakar measures abut against the Gondwana-Archæan boundary-fault. To the east of Chulhapora colliery, the rocks of the Pusai conglomerate stage are exposed, mainly to the north of the Pusai *nala*, and although the Pusai seam actually fails to crop out, there is little doubt that it would be met with below these pebble-bearing sediments. Immediately south and west of Kosumkanali, these lower conglomeratic Barakar measures are largely hidden by alluvium, but to the north of the village the basal

The Kosumkanali area.

hard Barakar sandstones are again exposed, and abandoned incline-workings, into what is evidently the continuation of the Pusai seam, are observed. From

the exposures of these basal beds, it is suggested that a small cross-fault traverses this alluvial tract west of Kosumkanali village; no evidence of any dislocation is, however, noticeable in the continuous Barakar outcrops just south of the Pusai, indicating that the fault has died out in this direction. The basal Barakar sandstones continue to crop out at intervals along the track running a short distance north of Bhalkhuria and Topatand villages, and in the stream flowing southwards to join the Pusai near Badhna a clear section of the Pusai conglomerate stage is exposed.

The Topatand-Khusori section.

This section closely resembles that of the Baraigarha-Chapapur area to the west, and includes, in descending order:—

Coarse grey and yellow felspathic sandstones with rounded quartzite boulders.
Thick seam of *coal* and shaly *coal* with shale bands. (Pusai seam.)
Grey sandstones and shaly sandstones, 25 to 30 ft.
Dark grey carbonaceous shale, 6 ft.
Grey and brownish bedded sandstones with shales.
Grey carbonaceous shales, 5 ft.
(Yellow-brown sandstones and sandy shales—uppermost Talchirs.)

The dip of these beds is to S. 35° W. at 12°. The Pusai seam has been worked in the past in the vicinity of the *nala* and at Topatand colliery, a short distance to the west. Following a general south-east by east direction, the basal Barakar measures continue beneath the alluvial soil in the vicinity of Madandih and Khusori villages. The conglomeratic sandstones are not exposed, though, what is evidently the equivalent of the Pusai seam has been worked in the past from inclines and shafts just south of the latter village.

ii. Kanauri coal measures.

This term has been applied to the group of coarse sandstones and shales, with several included coal seams of varying thickness, occupying the low ground in the vicinity of the Pusai stream and forming the Ramkanali-Rangamati ridge to the south. The included coal seams have been worked in the past from inclines in the vicinity of Dhura and on either side of the Pusai *nala* to the north of Rangamati, including Kanauri colliery. The majority of these workings are now closed and, as a result, first-hand information is often lacking. To the north of Rangamati, these strata, underlying the massive coarse grits of the ridge to the south, are largely

hidden by alluvium, but further west in the vicinity of Dhura, they are fairly well exposed. Massive grey sandstones with some shale intercalations overlie the Pusai conglomerates. In the southern bank of the Pusai and in the minor tributaries, which drain the high ground to the south, coarse-textured sandstones associated with the coal and shale beds are well-exposed, dipping almost due south at about 10° in the vicinity of Dhura; further east the strike is in an east-south-easterly direction. Just south of the Pusai, in the tributary due north of Ramkanali, the following succession is observed in descending order :-

The Dhura area.

Seam of shaly *coal* and shale, several feet thick.
Coarse sandstones ; 100 feet (approx.).
Seam of *coal* and shale ; 10 feet.
Grits ; 18 feet.
Grey shales ; 8 feet.
Massive yellow-grey sandstones ; 10 feet.
Seam of *coal* and shale ; ? 20 feet thick, including a 9-inch and a 3½-foot sandstone band in the upper part.

A short distance above this section the massive false-bedded sandstones include a fourth seam of shale and coal, several feet thick at its outcrop. The two lower coal seams of this section can be followed eastwards, cropping out in several small *nalas* just south of the Pusai stream.

A lower 7½-foot seam appears to have been proved a short distance below the above-described section and, judging from certain bore-hole records collected by Mr. Sethu Rama Rau, this seam is separated from the basal Pusai seam by about 275 feet of strata. Above this 7½-foot seam he notes the following succession in ascending order :—

Strata ; 70 ft.
Coal with *jhama* and shale bands ; 22 ft.
Strata ; 58 ft.
Coal including *jhama* with shale and sandstone bands, total 45 ft. (The coal ranges from 23 to 27 feet in thickness.)
Strata ; 23 ft.
Coal ; 7 ft.

Noting, however, that the majority of these workings are now closed, it is suspected that at least considerable portions of these Kanauri seams are of relatively inferior quality.

iii. Nirsa grits.

As the name implies, the strata of this stage include mainly the coarse, grey sandstones and grits that crop out in the vicinity of Nirsa village, and form the prominent Debiana-Ramkanali ridge to the west-north-west. To the east, these massive beds are well exposed in the Pusai stream-section, between the Grand Trunk road and the Kudia river. At least one main coal seam, of workable quality and thickness, is included within these sandstone strata. This seam is locally known as the Rangamati seam. It is probably the continuation of this coal seam that has been worked at the small colliery a short distance north of the Grand Trunk road, near Haraiajam village, and which continues south-eastwards *via* Nirsa village to Kudia colliery. To the west, as the main boundary-fault is approached, these beds swing round sharply to the south and south-east and continue almost parallel to the fault up to Kolika village. In the vicinity of the Grand Trunk road, these massive sandstones are seen to include a band of grey fireclay and black carbonaceous shales, intruded into by mica-peridotite near the tank just north of the road. The details of the strata included within this stage are exemplified in the following bore-hole section collected by Mr. Sethu Rama Rau :—

The Rangamati seam.

(*Bore-hole located near Haraiajam village.*)

	Ft.	in.
Soil	6	5
Sandstone	18	6
Shale	3	6
Coal	2	6
Sandstone and shale	12	3
Coal	6	6
Sandstone with shale	10	0
Coal	3	0
Sandstone	6	0
Coal	10	9
Jhama	4	0
Sandstone with shale	15	6
Coal	23	0
Shale	1	0
Trap		0
Shale and sandstone		6

K

iv. Kudia shales and sandstones.

Section in the Kudia *nala.*

The massive grits of stage (iii) are overlain by a succession of dark grey, carbonaceous shales and sandstones. These beds are well exposed in the Kudai river, in the vicinity of its junction with the Pusai and southwards to the East Indian Railway bridge, dipping S. 60° W. at about 10°. A dyke of white trap, 13 feet in total width, but split up into a number of parallel bands, cuts through these strata in the river-bed. Further north-west, to the south of Nirsa village, few exposures are visible. The strata of this stage evidently skirt the Kudia *nala*, to the south of Haraiajam and, swinging round to the south-west and south, recross the Kudia a short distance from the main boundary-fault. Within the carbonaceous shales of this group, in the eastern end of this Shampur basin, at least one seam of coal and shaly coal, reported to be 10 feet in thickness, is included. This seam has, however, not been worked in this area, and probably corresponds to the seam of coal, shale and fireclay—the Kudia seam—cropping out just north of the Kudia to the south of Gopinathpur.

v-vii. Shampur coal measures.

Kudia river-section south of Pithakiari.

For the purpose of a general correlation with the more eastern portions of the coalfield, this sequence of sandstone, shale and coal strata has been divided into three separate stages. Excluding the uppermost strata of stage (vii), these coal-bearing sediments of the Shampur basin, dipping south-inclined-west at about 20°, are intersected by the Kudia river as it flows southwards to the south of Pithakiari. This section is, however, very incomplete; sandy alluvium hiding many of the horizons. To the south-east of the village of Pandedih, the Kudia stream takes a sharp bend to the south-east and follows along the strike of the basal beds of stage (vii), and the upper strata of stage (vi). To the north of Shampur colliery, the Kudia river runs eastwards for a distance of about ¾ mile, and again traverses the Shampur coal measures. Within this portion of the river, a very clear and complete section of these upper Barakar rocks is exposed, dipping in a general west-south-westerly direction with moderate inclinations. Again, further east, to the south-

west of Mugma village, the river meanders in a south-easterly and southerly direction along the strike of the Kudia shale beds of the eastern edge of the Shampur basin. Between the Kudia river and the boundary-fault, to the north-east of Kolkund, the uppermost strata of the Shampur coal measures are exposed in the centre of the basin. A measured section of the Barakar succession, as exposed in the Kudia stream, has been quoted in detail by Dr. Blanford and were it not for the fact that a deep bore-hole, which has been put down within the Shampur basin by Messrs. G. Henderson & Co., Ltd., of Shampur colliery, gives a very accurate section of the greater part of this sequence, Dr. Blanford's section would have been well worth including in this description of the area. The succession indicated by the Shampur bore-hole is as follows :—

The Shampur area.

Shampur bore-hole (*see* Plate 16; Section I).

	Ft.	in.
Brown clays	9	0
Grey sandstone	11	0
Blue shale	5	6
Grey sandstone	32	6
Blue shale	2	0
Dark grey sandstone	10	0
Carbonaceous shale	2	0
Shale and shaly sandstone	62	0
Sandstone	30	0
(1) *Coal* (Top Fotka seam)	8	6
Dark shales	6	6
Grey sandstone	3	6
Shale	3	0
Coal	2	6
Shale and sandstone	8	0
Shales	11	0
(2) *Coal* (Lower Fotka seam)	12	0
Dark grey shales	7	0
Grey sandstone	96	6
(3) *Coal* 2 ft. 6 ins.		
Shale 3 ft. 6 ins.		
Coal 3 ft.	21	0
Shale 6 ft.		
Coal with partings 6 ft.		
Sandstone and sandy shale	11	6
Carbonaceous and sandy shale	11	6

Shampur bore-hole—contd. (*see* Plate 16; Section I).

	Ft.	In.
(4) *Coal* with bands	14	0
Sandstone	0	6
Sandy shale	1	3
Shaly sandstone	5	9
Shale	10	0
Sandstone	25	0
Sandy shale and sandstone	22	6
Shale	23	6
Trap	0	6
Shaly sandstone	13	6
Sandy shale	15	0
Shale and sandstone	32	0
(4a) *Coal, jhama* and trap in floor	6	0
Shale and trap	3	6
Sandstone	1	6
Shale	6	0
Sandstone	0	6
Shale	0	6
Shale and shaly sandstone	12	0
Blue shale	18	0
Grit	23	3
Blue shale	9	9
Shaly sandstone	4	0
(5) *Coal*	3	0
Shale	5	0
Coal with band	17	0
Coal with shale	9	6
Jhama and trap	3	6
TOTAL DEPTH	653	0

Five main coal-seams are passed through in this bore-hole and are clearly exposed at their outcrop in the Kudia section. Beneath seam No. 5, of the Shampur bore-hole, a 10-foot coal seam—No. 6 of Shampur—has been proved. Including the information derived from the Shampur colliery workings, the details of the coal seams of the Shampur basin are as follows:—

Coal seams of the Shampur basin.

No. 1 seam—Top Fotka seam, 10 feet.

Of good workable quality, now worked at Shampur colliery.
(Strata 10-13 feet.)

No. 1a, seam, 2½-3 feet.

Unworked.
(Strata 19 feet.)

No. 2 seam—Lower Fotka seam, **11-12 feet.**

Worked in the past at Shampur colliery.

(Strata about 110 feet).

No. 3 seam, **21 feet.**

Including shale bands. This seam has been worked in the past at Shampur colliery but is apparently of inferior quality.

(Strata 23 feet.)

No. 4 seam, **14 feet.**

Including shale bands. Like No. 3, this coal seam is apparently of inferior quality.

(Strata 150 feet.)

No. 4a seam, **6 feet.**

Including shale.

(Strata 80 feet.)

No. 5 seam, **about 40 feet.**

Including at Shampur colliery :—

***Coal* 3 ft.**

Shale 8 ft.

***Coal* 30 ft.**

***Jhama* and mica-peridotite up to 10 ft.**

Portions of this thick seam are apparently of good quality and are now being mined at Shampur colliery.

(Strata 12 to 20 feet.)

No. 6 seam, **10 feet.**

Including in the Shampur pits :—

***Coal* 2 ft. 6 ins.**

Shale 6 ins.

***Coal* 5 ft.**

Shale 6 ins.

***Coal* 1 ft. 4 ins.**

Overlying these beds to the south of the Kudia river, massive sandstones predominate and include, about 200 feet above the Top Fotka seam, a thin coal seam three to four feet in thickness. In the correlation given in a later chapter, it is suggested that these sandstone strata represent the uppermost of the Barakar measures. The overlying Ironstone Shale beds are, however, absent in this area.

Along the northern and north-western portions of the Shampur basin, seam No. 5 crops out in the vicinity of the Kudia, and is marked by a number of abandoned incline and shallow pit workings. Following the same south-westerly trend, the Top Fotka seam crops out in the north-western Shampur workings to the south of Pandedih, the dips steepening as the main boundary-fault is

approached. In the south-eastern part of the basin, to the south and west of the Kudia river, the strata again swing round in a more complete arc towards this fault. Numerous inclines and shallow pits, into the upper and middle seams, are observed at Shampur colliery and, within this area, from the deeper shafts, the lower seams (5 and 6) are being worked, their outcrops being indicated by old quarry workings to the east of Shampur village. In these south eastern areas, away from the main boundary-fault, the dips of the Lower Shampur coal measures are very gentle, but where they swing westwards and west-north-westwards and approach the fault to the south of Shampur village, the inclination steepens to as much as 25° to 30° to the north. Within the truncated anticlinal, which divides this south-eastern end of the Shampur basin from the Chatabar area, the steeply-dipping massive grits of stage (iii) form the higher ground to the north-west of Bandarchuan village. It is probable that the soft shale beds of the Kudia shale and sandstone stage have been to some extent attenuated in this zone of compression adjoining the boundary-fault.

The anticline separating the Shampur and Chatabar basins.

Closely adjoining this main fault, several outcrops of mica-peridotite dykes are observed traversing the Barakar measures, whilst others, at a greater distance from the boundary, complicate the workings of the Shampur area and probably link up with the sill-intrusions of Nos. 4*a*, and 5 seams. The resultant coking of the coal seams by these intrusions is well-illustrated in Plate 8, the prismatic structure of the coke adjoining the sill being particularly well-developed.

Mica-peridotite intrusions.

BIRSINGHPUR-MUGMA-CHATABAR AREA.

The structure of this tract of Barakar measures is very similar to that of the Pusai-Shampur area. To the north of the Kudia the lower Barakar rocks, overlying the Talchirs of the Merthadih-Dulabhdih area and unaffected by faulting, dip steadily to the south-west at moderate angles, but to the south of the East Indian railway-line the measures are more gently inclined. Between the Kudia *nala* and the main boundary-fault, the structure of the Shampur basin is repeated in the Chatabar-Josnadih area, though in this instance the upper Barakars are not preserved, the highest beds being the equivalent of the Middle Shampur coal measures. As at Shampur, the south-

Structure.

western edge of the basin is truncated by the main boundary-fault, the dips in the vicinity of this dislocation being very steeply inclined to the north-east.

The Barakars can be divided into the following stages, equivalent to those of the western area:—

vii. (Missing).
vi. (Upper part missing).
Upper Chatabar coal measures.
v. Lower Chatabar coal measures.
iv. Kudia shales (? 200 feet).
iii. Mugma grits (450 to 500 feet).
ii. Birsinghpur coal measures (400 feet).
i. Sasangberia conglomerates (300 feet).

i. Sasangberia conglomerates.

Coal seam at Merthadih.

Continuing south-eastwards from Khusori, these lowest Barakar strata are hidden by alluvium up to the Merthadih area. In the southern edge of the tank, just north of that village, however, the basal. hard, grey and ferruginous Barakar sandstones crop out. Slightly higher in the sequence a coal seam, indicated by a flooded incline. is included in these lowest measures. Little information could be gleaned regarding the seam of these old workings; it was suggested by the present colliery proprietors to include about five feet of coal, but of an inferior quality. With reference to the base of the Barakar measures and to the conglomeratic sandstones that crop out further south-east, this Merthadih coal seam may well be correlated with the thick Pusai seam of the west. There is good evidence, further south-east, that this coal seam passes into a seam of shale and shaly coal a few feet in thickness, so that its markedly decreased thickness in the Merthadih tract, as compared with the north-western extremity of the coalfield, is not surprising. The conglomeratic felspathic sandstones, which crop out to the south-east from beneath the alluvium, are of similar type to the Pusai beds of the north west.

ii. Birsinghpur coal measures.

Section in the collieries near Birsinghpur.

Above these basal conglomerates occurs a group of coarse sandstones and grits included among which are at least four coal seams, of varying thickness and quality. These measures undoubtedly correspond to those of the Kanauri-Dhura tract to the north-west. Details

of the coal seams of this stage can be obtained from the workings of Birsinghpur, Khode (Khoodia), and N. Phatka collieries, though most of these workings are, unfortunately, now closed. The succession, in ascending order, is as follows:—

(*a*) *Coal* seam of old inclines at eastern end of Khode colliery; may well be the equivalent of the 7-foot seam of Mahatadih colliery, ¼ mile south of Merthadih.

(Strata about 80 feet.)

(*b*) Khoodia main seam; now being worked at Khode colliery, 23-24 feet in total thickness; including a 10-foot section of workable coal of inferior quality. The details of this section are as follows:—

	Ft.	in.
Stone	1	0
Shale	0	9
Coal	3 to 4	0
Shale	0	6
Coal	3 to 4	0
Shaly *coal*	1	0
Coal	2	6

(The bottom 2 ft. 6 ins. is reported to be the best portion of the seam; the lower part of the seam is now being worked and largely converted into soft coke by open burning.)

(Strata, about 100 feet.)

(*c*) Seam of *coal* and shale said to be 35 feet in total thickness. (Several flooded inclines, including those of N. Phatka colliery to the west of the railway-siding, bear evidence of the outcrop of this seam, which is, apparently, of inferior quality and is now unworked. Sandy shales and shaly sandstones immediately overlie this *coal* and shale seam.)

(Strata including massive grits, about 100 ft.)

(*d*) *Coal* seam 3 to 4 feet, with about 7 feet of fireclay and sandy clays above.

(Massive grits).

These coal measures dip to S. 40° W. at about 11°. The seams, though including a large thickness of coal and shaly coal, are apparently, in a great degree, of inferior quality. At Mahatadih colliery to the north-west, the above-mentioned 7-foot seam includes a number of cylindrical masses of reddish-brown ironstone, oval to lenticular in cross-section, together with small nodules of iron-pyrites. These larger inclusions, on examination, were observed in some instances to be of a coarse granular structure, devoid of any definite arrangement, whilst others, less altered, showed a distinctly cellular, woody structure indicating an origin from the xyloid interior of fossilised branches or trunks of trees. Closely attached

Fossilised wood at Mahatadih colliery.

to this ferruginised interior was a thin layer of bright coal—vitrain—evidently derived by the alteration of the cortical and cambial tissues of the plant. At Kodokiari colliery to the north-west of Mahatadih, the following section is reported in the colliery inclines:—

Section at Kodokiari colliery.

	Ft.
Soil	22
Fireclay	1
Coal with shale bands	16

Below this seam, which is apparently the outcrop of seam (*b*) of Khodo colliery, an 8-foot seam is reported; this corresponds to the bottom seam of the latter area.

iii. *Mugma grits.*

Representing the south-easterly continuation of the massive grits of the Ramkanali-Nirsa area, the Mugma grit and sandstone strata, overlying the Birsinghpur measures, are well exposed in the Pusai stream between the Grand Trunk road and the Kudia river. Within these massive grits is included at least one thick seam of coal and shale varying, according to the various colliery records, from about 18 to 23 feet. The sections of the seam, as given on the mining plans of the different collieries, vary considerably, and usually represent a far greater thickness of coal with shale bands, than is actually worked or exposed in the colliery workings. On account of the lack of reliable boring information, and the uncertainty of the outcrop exposures, it is almost impossible to check the total thickness of these seams. In the case of these colliery workings near Mugma village the following sections have been recorded by Mr. Banerji:—

Sections at Mugma.

Pandra colliery.

	Ft.	in.	
Earth	9	0	
Sandstone	21	0	
Shale	1	6	
Coal	7	6	18 ft. 6 ins.
Shale	2	0	
Slatey *coal*	2	6	
Shale	0	6	
Coal	6	0	

About 125 feet above this thick seam is a seam of coal 3 ft. 6 ins. in thickness.

Chatabar North colliery.

	Ft.	in.	
Earth	2	0	
Sandstone	9	0	
Hard ferruginous stone	0	3	
Coal	0	6	
Shaly sandstone	4	9	
Shale	2	9	
Coal	0	3	25 ft. 6 ins.
Shale	1	3	
Coal	1	9	
Shale	0	8	
Coal	5	1	
Coal	2	6	
Shale	0	10	
Coal	7	6	
Black shale	2	0	
Shaly *coal*	2	6	
Shale	0	8	
Coal	0	6	

The dip is to the south-west at about 12°.

Within the grits above this main coal seam certain fireclays are intercalated, and have been worked on a small scale about half a mile south-east of Mugma village.

iv. Kudia shales and sandstones.

The Kudia shales and sandstones overlying the massive grits of stage (iii) are well exposed between the junction of the Pusai and Kudia streams and the East Indian railway-bridge, and continue to the south-east around Cheruinala village and southwards to the Kudia river. As the river is approached, the beds are very gently inclined. A short distance north of this village a 3-foot seam of coal crops out among these strata.

v. and *vi. Chatabar coal measures.*

Observations by A. K. Banerjee.

The Chatabar coal measures, apparently equivalent to the lower half of the coal-bearing strata of the Shampur area to the west, constitute the strata cropping out in the Chatabar basin. Regarding these measures Mr. Banerji makes the following observations :—

'Four coal seams appear to be included within this area. The topmost seam is 15 feet thick and crops out near the village of Sangamohul. The other three seams are very closely associated, separated by bands of shale, and their outcrops are

seen near the southern bank of the Kudia river. The highest of these three seams is 4 feet thick, the middle one 8 feet, and the lower one 30 feet thick. The 8-foot seam is said to be a good coking coal. The 30-foot seam has been intruded into by a sill of mica-peridotite and much of the coal is therefore damaged.'

Observations by J. B. Auden.

In addition to the exposures near the Kudia river, the mica-peridotite intrusions and resulting *jhama* are well-exposed in the tributary flowing eastwards to the south of Sangamohul village. Not far below the Chatabar thick seam is a 9-foot coal seam. Regarding these coal seams, Mr. Auden writes:

'The grouping of the coals at Chatabar is as follows:—

Coal 15 ft. (Kharbari seam).
(Shaly sandstone 170 ft.)
Chatabar *coal* and *jhama* 40 ft. (approx.).
(Sandstone varying up to 15 ft.)
Coal 9 ft.

The Kharbari seam occurs at the top of the Chatabar basin. It has not been worked for some years, but will probably be re-opened by Messrs. Villiers & Co. The outcrop of the Chatabar main seam is an ellipse, but there are not adequate exposures near the boundary-fault to trace its southern continuation or failure. From the rapidity with which the strikes swing round near Sangamohul, it is probable that the coal is not cut off to any great extent by the boundary-fault against the metamorphics. Further, the dips close to the fault are often as high as 50° so that a much greater thickness of Barakars can be accommodated in a smaller horizontal distance. The coal is worked in three sections, only the top of which is of any value. The sections in the inclines at Chatabar colliery are as follows:—

(Roof—flaggy micaceous sandstone.)

No. 1 Incline.	Ft.	in.	No. 3 Incline.	Ft.	in.
Coal	4	0	*Coal*	9	0
Shale	2	0	Shale	0	4
Coal	11	0	*Coal*	11	0
Shale	6	0	Shale	0	9
Coal	18	0	*Coal*	8	9

The 9-foot seam, some 15 feet below the Chatabar thick seam, has been observed only at Bandarchuan. The area is riddled with mica-peridotite sills and dykes, and the discrepancies in the thicknesses of the coal may be explained by irregularity in the position of the invading sill-intrusions, converting the coal into *jhama*. Towards Josnadih, to the north-west, the top section of good coal is absent, while eastwards, the bottom section is greatly reduced. A belt of *jhama* and dyke-rock, over 100 yards wide, runs west-north-west to east-south-east through the basin,

and a line of bores put down near Sangamohul met *jhama* everywhere. The dip of the lower seams varies from 5° to 12° on the north and east sides of the basin. A bore-hole put down by Messrs. Villiers & Co., Ltd., near the 'O' of Sangamohul shows the following section :- -

	Ft.	ins.	
Soil	8	3	
Sandstones	6	9	
Coal	15	0	(Kharbari seam).
(Sandstones and shales, the latter more prominent in the lower horizons) . . .	129	9	
Coal	7	9	Chatabar thick seam 27 ft. 6 ins.
Jhama	4	3	
Grey shale and sandstone	1	6	
Black shale	0	9	
Jhama	6	0	
Mica-peridotite	1	3	
Jhama	1	3	
Mica-peridotite	1	6	
Jhama	2	9	
Mica-peridotite	0	6	
(? lower portion of seam not proved.)'			

KAPASARA-GARPHALBARI-DAHIBARI AREA.

Within this area, the lowest horizons of the Barakar series crop out above the Talchir beds in the Kanchandih-Kapasara locality.

Structure.

The strike of these beds, and of the Barakars as a whole, continues in a south-easterly by east direction. As far south as the East Indian railway-line the lower and middle Barakar measures dip steadily to the south-west at about 10°, but to the south of the railway, in the Gopinathpur-Garphalbari tract, the strata become horizontal and further south,

The Kudia synclinal.

continuing across the Kudia river, the older beds again crop out in the southern limb of the Kudia synclinal. In this southern limb, as we approach the boundary-fault of the Katiadih-Palabari area, the dips steepen considerably, and it is probable that certain horizons, particularly the soft shale and coal seams, fail to crop out on account of shearing and terminal creep in the vicinity of this main fault. Within this area, therefore, the newest beds occur along the middle of the syncline, in the vicinity of Gopinathpur. These Gopinathpur strata belong apparently to the Kudia shale stage of the western tracts, and none of the higher stages are represented within this section.

The Barakar rocks of this area have been divided into the following stages, approximately equivalent to those of the other portions of the coalfield :—

v. to vii. (Absent.).
iv. Gopinathpur shales.
iii. Garphalbari-Dahibari grits.
ii. (*b*) Bindabanpur coal measures.
(*a*) Kapasara coal measures.
i. Kapasara conglomerates.

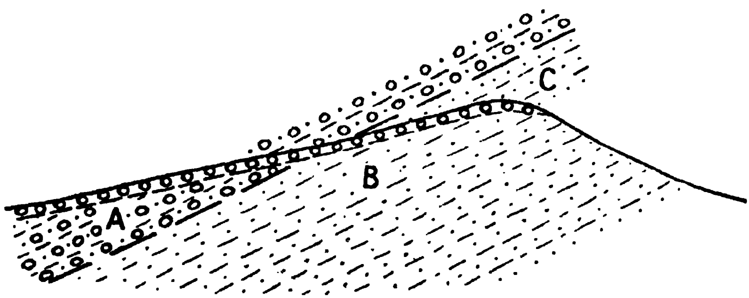
The detailed lithology and structure of these various rock-stages are as follows :—

i. Kapasara conglomerates.

Coarse gravels capping basal Barakars.

Throughout the Kuardih-Hirbana-Kapasara area, hillocks of basal Barakar sandstones, overlying the Talchir series, are capped with a coarse gravel consisting of well-rounded boulders of quartzite. The basal felspathic sandstones, which underlie this superficial gravel-bed, are well exposed in the small stream-section just east of Kapasara, and are almost devoid of quartzite pebbles. To the dip towards the Grand Trunk road, however, above these basal sandstones, the grey and white felspathic sandstones include numerous pebbles similar to those that comprise the above-mentioned gravels. These loose gravel-beds appear, therefore, to be residual to the boulder-bearing sandstones, which formerly continued to the rise above the basal Barakar beds, and which have since been removed by denudation. The following sketch-section illustrates the nature of these outcrops :—

Fig. 2.



A. Basal Barakar conglomeratic sandstones.
B. Soft sandstones of basal Barakar and uppermost Talchir horizon, with few or no pebbles; capping of quartzite pebbles, residual to the conglomeratic sandstones which once overlay them.
C. Capping of residual quartzite pebbles.

In the above-mentioned stream-section, alluvium, covering a narrow tract immediately below the pebbly sandstones, probably hides the outcrop of the diminutive representative of the Pusai-Merthadih seam. Within the boulder-bearing sandstones two thin shale and fireclay bands crop out to the north of the Grand Trunk road.

ii. Kapasara-Bindabanpur coal measures.

Within the Kapasara area, the coal seams included in the strata equivalent to the Birsinghpur coal measures, have apparently increased in quality and thickness and are separable into two fairly distinct zones:—

(*a*) **Kapasara coal measures.**

(*b*) **Bindabanpur coal measures.**

The main Kalimati-Egarcoor seam.

(*a*) *Kapasara coal measures.*—To the south of Kapasara, there coal-bearing strata crop out just south of the Grand Trunk road, but to the west and east they strike obliquely across the road to link up with the lower Birsinghpur measures of the west, and those of Agiarkund and Egarcoor to the east. Within the coarse-textured sandstones, which overlie the Kapasara conglomerates, an 8-foot coal seam, characterised by the presence of iron pyrites, is included. About 75 feet above this coal seam is the main Kalimati-Egarcoor seam. No attempt has apparently been made to work this seam from Birsinghpur in the west to within a short distance of Bindabanpur village. A short distance west of the latter village, however, the following section was noted by Mr. Auden in certain incline-workings:

(Sandstones)	Ft.	in.
Shale	4	0
Coal	7	6
Shale	1	6
Coal	7	0

Information was lacking regarding the substrata. Further south-east in the Agiarkund area, a coal seam, some 35 to 40 feet in thickness, crops out at approximately the same horizon within the lower Barakar measures, and is worked in a number of open quarries, inclines and shallow pits. To the east of the Dudhapanc

cross-fault the seam, thickening eastwards, is thrown to the north of the Grand Trunk road. The following are two representative sections noted by Mr. Auden, to the west and east of this cross-fault :—

Quarry-workings west of fault.

(Sandstones)	Ft.	in.
Fireclay	4	0
Coal	5	0
Shale	4	0
Coal and shales with fireclay .	25	0
(Floor of coal not touched).		

At Egarcoor on east side of fault.

(Sandstones)	Ft.	in.
Shale	8	0
Fireclay	4	6
Coal	1	6
Sandstone	3	0
Fireclay-shale	3	0
Coal	8	0
Shale	2	0
Coal	12	10

At Egarcoor, a pit was being sunk from the bottom of the 12 ft. 10 in. section of coal, and had, at the time of visiting, penetrated 23 feet of coal and shale, making the total thickness of coal over 40 feet. Much of the coal is of relatively inferior quality.

West of the Dudhapani fault, the dip of these measures is to S. 20° W. at about 7°; while to the east in the Egarcoor area, it is S. 10° to 20° E. at from 6° to 7°.

(*b*) *Bindabanpur coal measures.*—Massive sandstones with shales crop out above the thick Kapasara coal seam. Within these upper measures of stage (ii) a second thick seam of shale and coal is exposed in the flooded quarry-workings of Bindabanpur colliery, about a quarter of a mile south of Bindabanpur village, and continues east-south-eastwards, marked by a line of old outcrop-workings, largely collapsed as a result of surface combustion. On account of the inferior quality of the coal, most of these workings are now closed, so that it is difficult to obtain reliable information regarding the seam. Including shale bands, the coal seam appears to be of the order of 30 feet in thickness, and is overlain by shales and shaly sandstones. To the east of the Dudhapani fault at Agiarkund colliery, about 200 yards south of the Grand Trunk road, a 15-foot seam is recorded by Mr. Auden. Unlike the thick seam of Bindabanpur colliery, however, this coal seam is overlain by sandstones. A short distance below these coal seams, a second seam, said to be eight feet thick at Bindabanpur, is reported.

The Bindabanpur seam.

iii. Garphalbari-Dahibari grits.

The Gopinathpur seam.

There is no reason to doubt the equivalence of the massive grits that crop out at intervals on either side of the railway between Josnadih and Garphalbari villages, with those of the Nirsa-Mugma area to the west. The outcrops are almost continuous, and in both instances fireclays are associated, and the included coal seams show a marked resemblance to one another. The main seam in this stage is named the Gopinathpur seam. The following sections, taken from the reports of Messrs. Banerji and Auden, illustrate the Gopinathpur and associated coal seams as proved in the various workings of the Garphalbari-Gopinathpur area.

(1) West Barakar colliery.	Ft.	in.	(2) Gopinathpur colliery.	Ft.	in.	(3) Garphalbari colliery.	Ft.	in.
(Sandstone)			(Sandstone)			(Sandstone).		
Coal shale . .	6	3	Shale . .	5	6	*Coal* . . .	6	0
Inferior *coal* .	5	0	*Coal* . .	3	0	Sandstone . .	10	9
Stone . .	4	0	Stone . .	12	0	*Coal* . . .	13	0
Coal . . .	2	9	*Coal* . .	4	4			
Shale . .	3	0	Shale . .	1	6			
Coal . . .	17	0	*Coal* . .	10	0			

Seams of fireclay.

The coal is, however, of relatively inferior quality and is largely used either in the local brick works or made into soft coke by open burning. Occasional thin mica-peridotite dykes intersect these colliery workings. Within the grits, which overlie the Gopinathpur seam, several seams of fireclay are observed to the east of Gopinathpur and south of Garphalbari villages. These fireclay seams have been worked at and near their outcrops in several localities. They usually vary from 1½ to 2½ feet in thickness. To the east of the Dudhapani fault, it is suggested that the Gopinathpur seam crops out among the massive grits just north of the railway, and strikes across the east end of the eastern railway cutting of this area.

Outcrops near the Kudia *nala*.

The dip of the Gopinathpur seam, in the above-mentioned colliery workings is, in general, to the south-south-west at about 7°. As the Kudia *nala* is approached, however, the dip decreases almost to the horizontal and on the south side of the river a rapid change to a north-easterly to north-north-easterly inclination,

takes place, steepening rapidly to as much as 30° in the vicinity of the boundary-fault. On account of the west-north-westerly pitch of this Kudia synclinal, the Garphalbari grit stage, which crops out continuously between the villages of Garphalbari and Dahibari, is overlain by the Gopinathpur shale beds in the western part of the syncline. Within the southern limb of this syncline the strata of the Garphalbari grit stage, cropping out from Dahibari in the south-east, *via* Patasbana, to the Kudia river north of Chatabar village, includes a similar sequence of massive grits with fireclays, with at least one seam of shaly coal—the equivalent of the Gopinathpur seam. This coal seam has not been worked to the south of the Kudia, though the fireclays, occurring in this locality both above and below the horizon of the coal, have been exploited from a number of small quarries along the outcrop. The false-bedded, massive grits overlying the Gopinathpur seam are well exposed in the Kudia *nala* to the west of Jamdih, and from the evidence of the section observed in the bend of the river a little over half-a-mile west-north-west of Patasbana, these grits have diminished somewhat in thickness. In the steeply-eroded right bank of the Kudia at this point, the Gopinathpur seam forms an inlier, caused by a small cross-anticlinal traversing the syncline. The following measured section is observed (Auden):—

	Ft.	in.
(Massive grey grits)		
Mica-peridotite sill	2	0
Coal	1	0
Nodular blue shales	10	0
Grit	2	0
Splintery shales	3	0
Coal	8	0
Sandstones	3	0
Coal	2	0
Flaggy blue shales.		

(This section showing the regular outcrop of the sill across the Kudia stream, is illustrated in Plate 10, Fig. I.)

To the west of this inlier-exposure, the Gopinathpur seam can be recognised in the steeply-dipping grits of the tributary *nala* flowing northwards from Chatabar.

iv. Gopinathpur shales.

Overlying the massive grits of stage (iii) along the axis of the western part of the Kudia synclinal, and continuing north-west-

wards *via* Ragdih to link up with the Kudia shales of the Cheruinala area, are a group of shales, shaly ironstones, and flaggy sandstone strata, the Gopinathpur shales. These beds are well exposed between Gopinathpur village and the Kudia *nala*. Included within these measures is a seam of coal and fireclay—the Kudia seam—

Kudia seam just north of the Kudia *nala*.

well-observed in certain outcrop-workings in the northern bank of the Kudia, to the south of Gopinathpur. The section exposed is as follows :—

Massive and shaly yellow-grey sandstones.
Shaly sandstones and shales, 10 ft.
Dark shales and fireclay, 7 ft.
Coal, 6 to 7 ft.

Well-preserved leaf impressions of Glossopteris type occur within the carbonaceous shales that immediately overlie this coal seam. The strata being almost horizontal along the base of this synclinal the complexities of the outcrop of the Kudia seam, to the north of the Kudia river, are due to the irregularities of the surface topography. The coal appears somewhat shaly though where it occurs in conjunction with good quality fireclays, its profitable exploitation should be possible.

KALIMATI-KUMHARDUBHI-CHANCH AREA.

In contrast to the relatively simple structure of the above described areas to the west of the Dudhapani fault, the Barakar measures cropping out eastwards to the Barakar river

Complications due to faulting.

have been complicated not only by compressional forces, resulting in considerable changes in the dip and strike of the strata within certain areas, but also by a number of strike and dip faults of a throw, in certain cases, of several hundred feet. Such complications, combined with a paucity of outcrops and of very disjointed stream sections, render the elucidation of the detailed structure and the correlation of the various Barakar stages very problematical in certain instances. The absence of collieries working at the present time within large portions of this area, in particular the Dudhapani-Kumhardubhi-Chirkunda tract, or of reliable bore-hole records, add to these difficulties. In the Rajpura-Kalimati area to the north and the Chanch-Dumarkanda area to the south-east, however, the major displacements can, on the combined evidence of surface outcrops and colliery workings, be recorded with a fair degree of certainty.

The general structure has been discussed in an earlier chapter. Over the northern and middle portions of the area the strata strike in an east-south-easterly direction, dipping at gentle to moderate angles to the south-south-west. In the south-west portion, however, in the Kalian Chak-Patlabari area to the south-west of the Kudia river, the beds swing round rapidly to an approximately north-south strike, dipping eastwards at steep angles. The principal faults that traverse this area include :—

Structure.

(*a*) Dudhapani dip-fault, following a general north-north-easterly direction, across the western portion of this area.

(*b*) Rajpura-Siulibari fault, following a general south-easterly direction and with a downthrow to the north-east, across the north-western portion of the area.

(*c*) Mendha-Poradih faults.

(*d*) Kumhardubhi dip-fault (exact position doubtful).

(*e*) Chirkunda-Chanch dip-fault.

(*f*) Barakar river - Dumarkanda dip-fault.

To the north of the Grand Trunk road the large Rajpura-Siulibari fault, following a south-easterly trend, throws the lower Barakar rocks down to the north-east and causes the thick Kalimati seam to be thrown northwards from the Egarcoor tract. This fault appears to decrease in intensity to the south-east and possibly does not continue east of the Kumhardubhi dip-fault. About $\frac{3}{4}$ mile east of Kalemathi village, the Kalimati coal measures are cut out by the two large displacements of the Mendha-Poradih area, but further east around Barmundih, the normal lower Barakar succession again crops out. The rocks of the area around Kumhardubhi appear to include the middle Barakar measures, with the Laikdih coal measures, including the thick Laikdih seam, coming in to the south-east. The area, however, appears to be considerably complicated by faulting and its exact elucidation has not been possible. The lower portion of these middle measures is doubtless again represented to the north of Chirkunda, and further south, within the Junkundar-Kalian Chak area, where the strata swing round to the south, their outcrops are to some extent repeated by the southerly continuation of the Dudhapani faults. The upper Barakar rocks, including the Chanch-Dumarkanda seam in the upper part, crop out around Lakhdih village and southwards to Dumarkanda. West

of the Dumarkanda colliery-workings they are, however, intercepted by the Chirkunda-Chanch cross-fault, which throws the outcrop of the Chanch seam southwards to Chanch colliery. As in the case of the middle measures of the Kalian Chak area, these upper beds swing round to the south-east as the main boundary-fault of the Luhchibad areas is approached. The immense Barakar river dip-fault, with a downthrow to the south-east to the extent of several hundred feet, appears to cut across the Barakar river to the south-west of Duburdih and, skirting the western bank of the river in the vicinity of Chirkunda village, continues within the upper measures of the western bank and limits the workings of the Chanch seam to the east of Dumarkanda.

The Barakar measures of this area have been divided into the following stages, corresponding approximately to those of the more western tracts :—

vii. Chanch coal measures.
vi. Laikdih shales and sandstones.
v. Laikdih-Patlabari coal measures.
iv. Kalian Chak shales and sandstones.
iii. Chirkunda grits with coal seams.
ii. (*b*) Siulibari coal measures.
(*a*) Kalimati coal measures.
i. Rajpura conglomerates.

The details of these various stages are as follows :—

i. *Rajpura conglomerates.*

These basal Barakar rocks are well-exposed between Rajpura and Kalemathi, around Mendha village, and again in the Mangalmara area adjoining the Barakar river. The section of these basal beds as observed in the Kol Jor is as follows :—

Kol Jor section.

(*Ascending order*).

	Ft.
(Massive, softish, gritty sandstones, with small, rounded, quartzite pebbles.)	
Carbonaceous, sandy micaceous shales	1
Hard, grey, medium-textured sandstone, weathering reddish-brown	6
Carbonaceous shale	2
Hard, grey sandstone weathering reddish-brown . .	6
(Dark-coloured alluvium for a distance of about 20 yards, including a small outcrop of carbonaceous shale and ? *coal*).	
Thick, soft, gritty, white and grey conglomeratic sandstones with rounded pebbles of quartzite. These beds include at least one thin band of shale or fireclay.	

ii. (a) Kalimati coal measures.

These coal-bearing strata of the lower Barakar measures, representing the easterly continuation of the Egarcoor beds, crop out in the area south and west of Kalemathi village between the Rajpura and Mendha faults, and again in the Barmundih tract between the Poradih and the Barakar river displacements. The succession is fairly well exposed in the Kol Jor and includes a thin coal and shale seam just above the conglomeratic sandstone zone, followed by sandstone strata within which the thick Kalimati seam is intercalated. Shaly sandstones followed by massive sandstones, overlie this thick coal seam and include an upper seam about six feet in thickness. The Kalimati seam of the quarry-workings to the west of the Kol Jor is, apparently, about 50 feet in thickness, including shale bands. To the east of the present quarries, it is intersected by mica-peridotite sill-intrusions, the resultant *jhama* coal being exposed at the outcrop in the Kol Jor. Similar intrusives are perhaps more widespread within the seam of the Barmundih area, and can be well observed in the tributary stream a short distance west of the village.

ii. (b) Siulibari coal measures.

These strata include the beds of shale, sandstone, and impure coal that crop out to the dip of the Kalimati workings, just north of Siulibari village. They appear to represent the easterly extension of the Bindabanpur coal horizons, though it is suggested that the beds as a whole, together with the included coal seams, have thinned considerably eastwards, and are insufficiently defined in the areas east of the Kol Jor to justify their classification under a separate name. Shales and shaly sandstones, with ironstone bands, predominate and include at least one fairly thick seam of coal (probably of very inferior quality), which has been worked in the past in the now flooded diggings just north and west-north-west of Siulibari village. The dip of these strata is of the order of 12° to 15° to the south-west and south-south-west.

iii. Chirkunda grits, with coal seams.

Occurrence and lithology.

That the strata of this stage crop out between Chirkunda and the Barmundih area is proved fairly conclusively, and that they recur in the vicinity of the metamorphics to the north-east of Patlabari village is, in the writer's opinion, equally certain. More doubtful,

however, is the suggestion that the exact equivalents of these beds continue west of the Chirkunda-Sarsa Pahari area into the Siulibari-Kumhardubhi tract, though the writer is inclined to this view. To the north of Chirkunda, the beds include the typical massive, coarse grits and sandstones, with associated fireclays and coal seams, in general resembling the strata of the Garphalbari grit stage to the west. The coal seams have, however, thickened in these

Coal seams of Chirkunda.

more eastern areas, as is shown by the Chirkunda bore-hole section (Plate 16, bore-hole 2) and the coal has been partly converted into *jhama* as a result of ultra-basic intrusion. One of these coal seams has apparently ignited at its outcrop, the resultant reddish shales and scoria being well exposed to the north of the railway line. Similar coarse grits with included fireclays occur in the Kol Jor and westwards near Siulibari village, and a flooded quarry-working just west of the Kol Jor, a short distance south of the Grand Trunk road, probably represents one of the seams of this stage. Unfortunately, the records of several bore-holes of the Kumhardubhi

Kumhardubhi area.

area could not be found. East of the Engineering Works, however, are several flooded quarry-workings, marking the outcrops of two closely-associated coal seams. These are reported to include a lower 11-foot seam, separated by a relatively small thickness of soft and shaly sandstone with shales from a 6-foot seam. The dip is at a very gentle angle to the south-inclined-west. It is very probable that these coal seams belong to the middle Barakar measures, but on account of the lack of continuous exposures, without further information from bore-holes, it is impossible to dogmatise on the question of their exact correlation.

To the south-west of the Kudia stream, an association of grit and sandstone strata, with fireclays and attenuated seams of coal,

South of the Kudia stream.

swings round to the south and south-east obliquely parallel to the main southern boundary-fault. These beds represent the continuation of the Dahibari grit measures of the southern side of the Kudia syncline, but are, in this area, north of Patlabari, further disturbed by the southern extension of the faults of the Dudhapani area in addition to the shearing and attenuation that has resulted from their association with the main boundary-fault to the south. The fireclays of this area are, however, being worked.

iv. Kalian Chak shales and sandstones.

Overlying the grit, fireclay and coal strata of the Chirkunda grit stage in the stream-section to the south of Kalian Chak, south-west of the Kudia river, is a series of alternating shales and sandstones including at least one thick band of carbonaceous shale and shaly coal. These beds, resembling the Kudia shales of the west, are partially repeated by faulting in this area.

v. Laikdih-Patlabari coal measures.

Overlying stage (iv), of the Kalian Chak area, is a succession of sandstones and shales including the thick coal seam of Patlabari colliery, north-west of Patlabari village. From a study of the lithological sequence of these middle Barakars, the writer is convinced that these measures are the equivalent of the Chatabar and Lower Shampur coal measures of the western end of the field. They appear to be represented to the north-east of the Kudia river by the sandstones and associated thick coal seam of the Junkundar village area, across which tract of country the outcrop of the seam is burnt and the overlying sandstone strata locally indurated and converted into semi-quartzites, brecciated and intermingled with burnt shale as a result of the subsidence that followed the burning of the seam. The Kumhardubhi cross-fault cuts off this Junkundar outcrop to the east. Across this fault it is suggested that the thick coal seam and associated strata of the flooded 'Laikdih' quarries, to the south-east of Kumhardubhi, represent the easterly continuation of these coal measures. The area is undoubtedly traversed by several large faults, and in the absence of bore-holes or continuous sections, it is impossible to bring forward any positive evidence in support of this view. What lithological evidence there is, however, tends to suggest this correlation, the associated strata being similar in both cases, whilst in order to regard them as different seams would necessitate an unprecedented amount of lateral variation within these Barakar measures of which there is no evidence. To what exact horizon the 5- to 6-foot seam of Jagraj colliery, to the south of the Laikdih quarries, can be designated, is debatable. The following details in connection with the thickness of these coal seams are given by Mr. Auden.

Patlabari-Junkundar area.

Flooded 'Laikdih' quarries.

The section of the thick coal seam at Patlabari colliery is as follows :—

	Ft.
Good *coal*	8
Coal and shale	27
Jhama	5
Coal	5
TOTAL	45

This is underlain by fireclays and extensive sills of mica-peridotite, so that it is possible that the full thickness of the seam is not included in the above section.

Near Junkundar, about 15 feet of burnt coal overlie about 12 feet of fireclays and pipe-clays. Assuming an ash-content of 20 per cent., the initial thickness of this seam may have been of the order of 75 feet.

Regarding the Laikdih seam of the flooded quarries south of Kumhardubhi, the total thickness is given as approximately 90 feet, including 82 feet of coal, with *jhama* in the lower sections.

vi. Laikdih shales and sandstones.

Beneath the Chanch coal measures in the vicinity of Lakhdih (Laikdih) village, a succession of massive sandstones, including a thick seam of carbonaceous black shales is exposed. The upper sandstones of this sequence include rounded quartzite and semi-quartzite pebbles.

vii. Chanch coal measures.

Within this area, immediately west of the Barakar river, the uppermost beds of the Barakar series comprise a number of alternating massive sandstones, shaly sandstones and shales, within which are included two coal seams. Of these seams the lower one—the Chanch-Dumarkanda seam—is of a thickness of 10 feet and of excellent quality. About 200 feet above, a thin coal seam has been proved in a bore-hole to the dip of the Dumarkanda workings. The writer suggests that these measures are equivalent to the uppermost stage of the Shampur area, but are unrepresented in the sequence between Shampur and Chanch. South-west of Chanch, these bed

swing round to the south-west and south obliquely to the main boundary-fault, the dip steepening considerably in the vicinity of the fault. In this locality, south-west of the Kudia river, the continuation of the Chanch seam has been worked at Luhchibad colliery. About 250 feet above this seam the Ironstone Shales overlie these uppermost Barakar measures.

II.—Ramnagar-Itapora area.

This area includes the continuous tract of Barakar measures that crops out eastwards of the Barakar river for a distance of about 9½ miles up to the line of the Panuria-Itapora cross-fault. This latter displacement forms a tectonic divide between the above mentioned Barakar outcrops and the Gourangdi-Jamgram portion of the coalfield to the north-east. The general simple structure of these measures, dipping southwards and south-south-eastwards at gentle to moderate angles away from the northern limit of the coalfield, is complicated by a number of dip-faults, some of which appear to die out within the lower Barakars of the northern part of the field. Over the greater length of the tract, these lower Barakar outcrops succeed the uppermost Talchir beds, and the uppermost measures are overlain by the basal Ironstone Shales. In the western portion of the area, however, the measures are limited both to the north and south by large strike-faults, including the Debipur-Lakrajoria fault in the north, which cuts out the whole of the Talchir series over a portion of its length, and the Begunia-Petana displacement to the south, which throws the Ironstone Shale beds down against the various horizons of upper Barakar age. For the convenience of description this Ramnagar-Itapora area may be subdivided into the following four localities (*see* also Table 4) :—

Structure.

1. **Damagaria-Lalbazar-Begunia area.**
2. **Bonjumari-Salanpur-Bahira area.**
3. **Alkusha-Dharmma *nala* area.**
4. **Nandai-Shyamdi-Baliapur area.**

Structurally, as a result of faulting, the two former areas are more or less distinct.

The strata of these four areas are divided into the following seven stages (*see* Table 4) :—

Table 4.—Ramnagar-Itapora area (4-inch sheets Nos. 4 and 8).

STAGE.	DAMAGARIA—LALBAZAR—BEGUNIA AREA.	BONJUMARI—SALANPUR—BAHIRA AREA.	ALKUSHA—DHARMMA *nala* AREA.	NANDAI—SHYAMDI—BALIAPUR AREA.
vii.	Begunia coal measures . .	Rampur coal measures . .	Upper and middle Barakars of the Phulberya-Khudka area; stages undefinable on account of paucity of outcrops and bore-hole records.	Upper and middle Barakars of the Parbbatpur-Amlala area; stages undefinable on account of paucity of outcrops and bore-hole records.
vi.	Lalbazar shales and conglomerates	(Largely absent as a result of faulting.)		
v.	Ramnagar-Laikdih coal measures	Upper Bahira coal measures .		
iv.	Duburdih shales and sandstones .	Chanpataria shales and sandstones.		
iii.	Pebbly grits with coal seams, (proved in bore-holes at Ramnagar).	Lower Bahira coal measures. Upper Salanpur grit and coal measures.	Dhundabad-Mutachandi grits .	?Shyamdi-Amdiha-Itapora grits
ii.	Damagaria coal measures . .	Lower Salanpur coal measures .	Alkusha-Radhaballavpur coal measures.	Paharpur-Alipur coal measures.
i.	Basal conglomerates . . .	Bonjumari conglomerates . .	Radhaballavpur conglomerates .	Nandai conglomerates.
— — —	— — —	— — (TALCHIRS). — —	— — —	— — —

The detailed geology of these various areas is as follows:—

DAMAGARIA-LALBAZAR-BEGUNIA AREA.

This area adjoining the Barakar river, is bounded on the north by the Debipur-Lakrajoria strike-fault; on the east by the Salanpur-Chanpataria and Bahira dip-faults, and on the south by the large Begunia-Petana strike-fault. Other important displacements within the tract include the north-west continuation of the Bahira dip-fault, which cuts off the thick Damagaria coal seam to the south-west of Damagaria colliery, and the two roughly parallel faults that, following a north-east to south-west direction, form a narrow elongated *horst* between Ramnagar and Lalbazar. The dip of the measures within this area is usually to the south or south-south-east at relatively gentle angles, varying from 11° at Damagaria, to 7° in the Ramnagar-Lalbazar area, but decreasing to 3° at Begunia. To the north-east of Lalbazar, however, the beds swing round to the north and north-west, obliquely parallel to the Bahira cross-fault, the dip being at a gentle angle to the east. The area is intersected by two dolerite dykes, and a number of mica-peridotite dykes and sills, the latter being apparently confined to the middle and upper Barakar measures.

Faults.

Intrusions.

As to the west of Barakar river, the Barakar measures of this area can be divided into the following seven, approximately equivalent stages:—

vii. Begunia coal measures.
vi. Lalbazar shales and conglomerates.
v. Ramnagar-Laikdih coal measures.
iv. Duburdih shales and sandstones.
iii. Pebbly grits with coal seams.
ii. Damagaria coal measures.
i. Basal conglomerates.

Within this area, the coal seams of the Barakar measures appear to have reached their maximum development and, as a result of the relatively good outcrops and the considerable amount of available colliery and bore-hole information, the elucidation of the lithology and structure has been attended with a fair degree of success. The details of the various stages are as follows:—

i. Basal conglomerates.

Between Debipur and Damagaria colliery the basal conglomerates are well exposed, but to the west and east these outcrops are cut

out by the two faults that intersect the area a short distance south-west of Damagaria and just east of the Jamaldih quarry respectively. Below the thick pebbly sandstones, a thin outcrop of coaly shale is included in the basal sandstone succession.

ii. Damagaria coal measures.

The coal-bearing strata of this stage also crop out within the Damagaria-Jamaldih area, above the basal conglomerate beds. To the south-east of Duburdih, these measures are faulted down by the north-westerly continuation of the cross-fault that runs between Bahira and Lalbazar collieries, and the south-westerly continuation of the Debipur-Lakrajoria cross-fault. These lower measures doubtless occur in depth only a short distance below the bottom of the deep bore-hole of the Ramnagar area (Plate 16, bore-hole 3.) Within the sandstone and shale strata of this stage, the thick Damagaria coal seam is included. No bore-hole records, to the dip of this seam, are available, though the seam is reported to be of a total thickness of at least 100 feet, including shale bands. The section in the Damagaria quarry-workings (*see* Plate 11) as given by Mr. Auden, is as follows:—

Damagaria seam.

	Ft.
Fireclay, passing into *coal* to the dip	20—30
Top *coal*	17
Good *coal*	6
Coal with shale bands	6
Good *coal*	27

Sections of the lower portion of the seam are being worked. The coal, largely composed of durain, is in general of a dull colour, but is apparently a very suitable steam-coal.

iii. Pebbly grits with coal seams.

This succession of coarse-textured sandstones with associated seams of coal and fireclays, includes a total of about 450 to 500 feet of strata overlying the Damagaria stage. The upper part of this sequence is represented in the outcrops of the stream-section about a quarter of a mile east of Duburdih, where the beds abut against the south-westerly continuation of the Debipur-Lakrajoria fault. The higher beds of this stage probably crop out between the fault that limits the Jamaldih colliery workings to the south-east and the Chanpataria-Dendua displacement. These outcrops include massive grits with fireclays, followed above by what appears

to be a thick coal seam, locally exposed in a flooded quarry just north-west of the Chanpataria-Dendua fault, about 550 yards south of the Jamaldih quarry. No particulars were, unfortunately, available regarding this coal seam. The full sequence is, however, represented within the deep bore-hole section of the Ramnagar area (Plate 16, bore-hole 3) between, approximately, levels 300 and 800 feet. The upper seams of this section, representing as they apparently do the lower seams (4 and 5) of Bahira colliery to the east, have been largely converted to *jhama* by the intrusion of mica-peridotite. As a whole, the strata of this stage are regarded as equivalent to the beds of the Chirkunda grit stage to the west of the Barakar river. Although the included coal seams show considerable lateral variation, the general resemblance in lithology points to this conclusion. This is also borne out by a study of the Barakar succession and the geological structure of the two areas.

Deep bore-hole at Ramnagar.

iv. Duburdih shales and sandstones.

These shale and sandstone beds, with an included thin seam of coal, crop out below the thick Laikdih seam to the south of Duburdih. The beds appear to represent the equivalent of the Kudia shale stage of the western end of the coalfield, though to the east of the Barakar river they have thinned considerably and include not more than 150 feet of almost unproductive strata.

v. Ramnagar-Laikdih coal measures.

The strata of this stage include two of the most important coal seams of the Barakar measures—the Ramnagar and Laikdih seams. These closely associated coal seams crop out in an arc just north of Ramnagar village. On the south-east side of the 90-foot fault that traverses the Barakar measures in a north-east to south-west direction, about a quarter of a mile south-east of Ramnagar village, the topmost strata of this stage, including the Ramnagar coal seam (worked from No. 5 Incline, Ramnagar colliery) crop out again in a small arc, convex to the south, along the narrow tract within this Ramnagar *horst*, but a short distance further south-east they are again thrown down by the approximately parallel fault that bounds the tract on the Lalbazar side. Regarding these two *horst*-faults, it is suggested that they run together and die out a short distance to the south-west of these Ramnagar workings. At least there is no perceptible

Faults at Ramnagar.

interruption of the higher shale and pebbly sandstone measures (of stage vi), which form a continuous outcrop from just north of Lalbazar, westwards to the Barakar river about a quarter of a mile north of Manberia village.

Ramnagar seam.

The upper, Ramnagar seam, is from 12 feet to 13 feet 6 inches in thickness and includes, at Ramnagar colliery, a 10- to 15-inch shale band about two feet from the floor. The seam is of excellent quality, in parts exhibiting a marked 'ball-structure'. It includes a large proportion of vitrain and, when caked, yields an excellent metallurgical coke. Unfortunately to the south, in the area north of Balltara and Kendua, and again in the shafts at Lalbazar colliery, the seam is intruded by mica-peridotite sills and is, at least in part, converted to *jhama.*

Laikdih seam.

The Laikdih seam is separated from the Ramnagar seam by strata, mainly of sandstone type, increasing eastwards to just over 100 feet. At the outcrop, the seam is associated with much mica-peridotite and *jhama*, especially towards the top. In the inclines of Ramnagar colliery, the coal seam has been proved up to 30 feet in thickness including shale bands, but to the dip, the numerous bore-hole sections denote a much greater total thickness, varying up to nearly 70 feet. This maximum thickness, however, includes a large proportion of *jhama* and possibly some mica-peridotite rock. At Lalbazar colliery to the east, the seam comprises :—

	Ft.	in.
(*a*) *Coal*	10	0
Mainly sandstone	12	0
(*b*) *Coal*	5	9
Sandstone	9	0
(*c*) *Coal* (approx.)	40	0

The upper seam (*a*) includes a 3-inch shale band about seven feet from the floor. It is a seam of excellent quality, composed largely of bright coal, and yields a good metallurgical coke. The middle seam (*b*) appears from the analysis to be slightly inferior in quality to the upper seam. Of seam (*c*), 35 feet of coal, including a number of thin shale bands, have been actually proved, below which there is a certain thickness of *jhama* of which three feet have been proved, though the whole thickness has apparently not been passed through. This 35-foot seam includes several bands of nodular bright coal of excellent quality, alternating with intercalations of dull 'boney'

coal of a much higher ash-content. Certain sections of this thick seam yield a good metallurgical coke; these include the bottom 6-foot section.

As in the case of the Ramnagar, the Laikdih seam has been proved by bore-holes to be partially converted into *jhama* within certain tracts of the Manberia-Balltara area, and also in places adjoining the Ramnagar *horst* to the south-east of Ramnagar village.

vi. Lalbazar shales and conglomerates.

In contrast to the underlying Ramnagar-Laikdih coal-bearing stage, these strata, including about 550 to 650 feet of alternating thick massive sandstones, shaly sandstones and black carbonaceous shales, are entirely unproductive. The lower massive sandstones with some included pebbles, occupy the sloping ground around and south of Ramnagar village and near the northern shafts of Lalbazar colliery. The thick succession of black shales crop out at intervals in the low-lying ground to the south of Ramnagar and north of Lalbazar, and are overlain by conglomeratic sandstones, which can be followed continuously from just north-east of Lalbazar village along the prominent low ridge that runs westwards to the Barakar river. From a comparison of the lithological sequence of the Barakar measures of the two areas, the writer suggests that these unproductive beds are represented in the extreme west of the coalfield by the middle Shampur coal measures.

vii. Begunia coal measures.

These coal-bearing strata, including a thickness of about 205 feet, represent the topmost horizons of the Barakar measures. They are doubtless equivalent to the beds associated with the Chanch-Dumarkanda coal seam to the west of the Barakar river, and to the Upper Shampur coal measures of the western extremity of the coalfield. The Begunia coal measures include in descending order :—

Begunia sandstones, including massive sandstones with intercalated shaly sandstones and shales, and one 3-foot coal seam	Total thickness 105 ft. (approx.).
Begunia shales, including thick, black, carbonaceous shales cropping out just north of the Inspection bungalow Massive sandstones, passing laterally into shaly sandstones and shales to the east.	Total thickness 100 ft. (approx.).
Begunia seam	10 ft.

The Begunia seam, worked at the pits of Begunia Khas colliery, is an excellent seam of relatively uniform thickness throughout this area, though further east it appears to decrease in thickness. Like the Ramnagar and Laikdih seams it includes a proportion of very bright nodular coal. Its outcrop can be traced almost continuously from Barakar village to Petana. Near Balltara it has formed the horizon of extensive mica-peridotite sill-intrusions.

Begunia seam.

The outcrops of these Begunia measures are limited to the south by the Begunia-Bahira strike-fault. Skirting the southern edge of Begunia village, this displacement, with a downthrow of about 400 feet to the south, brings the Ironstone Shales against the Begunia sandstones at an horizon about 200 feet above the Begunia seam; but further east, owing to the fault cutting slightly obliquely to the strike of the measures, the Ironstone Shales abut against lower horizons of this stage. On the south side of this main fault the Begunia seam has been proved below the Ironstone Shales, but the area appears to be further disturbed by displacements. The workings of Begunia Khas colliery extend westwards beneath the greater width of the Barakar river, the large cross-fault that separates this tract from the Chirkunda-Dumarkanda area being, apparently, located not far from the western bank of the river.

Begunia-Bahira strike-fault.

BONJUMARI-SALANPUR-BAHIRA AREA.

This area includes the colliery-workings of Bahira (Borrea), Salanpur, Banbirdi and Rampur. To the north, the basal Barakar rocks overlie the Talchirs; to the west, the area is bounded by the Dendua-Chanpataria cross-fault in the north and the Bahira cross-fault in the south; to the east, a large cross-fault separates the lower Barakar outcrops of Banbirdi from those of Alkusha; whilst to the south, the continuation of the Begunia-Bahira strike-fault throws the Ironstone Shales down against various horizons of the upper Barakars to the south of Bahira colliery. A large cross-fault, the Bhagrand-Salanpur fault, following an approximately north-east to south-west direction, separates the Dendua and Banbirdi colliery areas. In addition, a large strike-fault, possibly the deflected continuation of the Bhag-

Structure.

rand-Salanpur fault, cuts across the tract to the north-west of Sabanpur village, and with an upthrow to the south, repeats the outcrops of the higher measures of the Dendua area, within the Chanpataria-Salanpur tract. A steady dip at a gentle angle to the south or south-east prevails over a large part of the area, but in the vicinity of the faults this is liable to considerable variation.

Intrusions.

The 20- to 30-foot Lachhmanpur dolerite dyke intersects the south-western part of this area and a number of dykes and large sill-intrusions of ultra-basic type are met with, the latter being prominent within the middle-lower measures of the Chanpataria-Digari-Sabanpur tract.

The Barakar measures of this area can be conveniently divided into the following seven stages approximately equivalent to those of the above-described more western portions of the coalfield :—

vii. Rampur coal measures.
vi. (Largely absent, as a result of faulting).
v. Upper Bahira coal measures.
iv. Chanpataria shales and sandstones.
iii. Lower Bahira-Upper Salanpur coal measures.
ii. Lower Salanpur coal measures.
i. Bonjumari conglomerates.

The details of these various stages are as follows:—

i. Bonjumari conglomerates.

These pebbly sandstone beds, cropping out occasionally between Bonjumari colliery and Basudebpur, and again at the base of the Barakar measures of the Banbirdi tract, are doubtless equivalent to the basal rocks of the Lower Damudas to the west. These beds are reported to include one thin 2-foot seam of coal—the Farewell seam.

ii. Lower Salanpur coal measures.

The measures of this stage, including the thick Salanpur 'A' seam, form a curved outcrop running between Bonjumari and Bhagrand collieries within the Dendua trough, while to the east of the trough they follow a more direct north-easterly trend north of Banbirdi village. At Salanpur colliery, just within the trough, these lower measures have been proved at a depth of about 500

feet, (*see* Plate 16, bore-hole 10)*. The strata of this stage include :—

	Ft.	
Coal	7 to 10	(Salanpur 'B' seam).
Sandstone, varying from . .	25 to 40.	
Coal, with shale bands . . .	100 to 125	(Salanpur 'A' seam).

Salanpur 'A' seam.

The lower seam 'A', undoubtedly the equivalent of the thick Damagaria-Kalimati seam of the west, is reported to reach a total thickness of 125 feet, of which the lower 25 feet is of the better quality and yields a useful steam-coal which, like the basal Barakar seams of the other areas, is composed largely of dull coal. Lenticular-shaped nodules of hard ironstone are included within the seam. The outcrop of the seam is marked by a number of large quarry-workings, of which only that of Bhagrand colliery was being developed at the time of the present survey. The upper seam 'B' is, apparently, of inferior quality and was not being worked.

Further to the dip, these basal Barakar seams have been proved in the bore-holes of the Digari-Sabanpur area (*see* Plate 16, bore-holes 6—9). This area, traversed by at least one strike-fault causing the repetition of certain of these lower Barakar measures, is intersected by a number of mica-peridotite dyke and sill-intrusions evidenced both at the surface and within certain of the coal seams in depth.

iii. Lower Bahira-Upper Salanpur coal measures.

Repetition by strike-faulting.

As a result of the above-mentioned strike-fault these coal-bearing measures, including about 450 feet of strata, are repeated within the Bahira-Dendua tract. Dipping about 11°, these beds, overlying the basal Salanpur seams, crop out between the Dendua-Salanpur trough-fault in the form of a sharp synclinal, pitching steeply to the south-south-west. They recur, to the south of the strike-fault, within the Chanpataria-Sabanpur tract to the west and north of Bahira village. The sequence of the beds is well illustrated in the bore-hole sections of the Digari-Sabanpur area. The lower 375 feet of this succession comprise coarse felspathic grits and sandstones, with grey shales and fireclays, included among which are several coal seams, apparently

* The correct position of this bore-hole is about 500 yards north-east of Dendua colliery. It was incorrectly located on the 4-inches to one mile sheet (No. 8); this error has been rectified on the one inch to one mile map (Plate 19).

of relatively inferior quality, and attaining a maximum individual thickness of about nine feet. At the top of this stage, however, are two closely-associated coal seams of considerable economic value, including the Salanpur 'C' and 'D' seams of the Dendua area, and the equivalent Bahira '5' and '4' seams of Bahira colliery. The sections within these two areas are as follows :—

Dendua area.	*Bahira area.*
Coal 5 ft. (Salanpur 'D' seam) Sandstones about 40 ft.	*Coal* 5 ft. (Bahira '4' seam) Strata about 40 ft.
Coal, variable, often including a 3- to 5-foot sandstone band, separating a 4½-foot top section from a 16- to 18-foot lower section. (Salanpur 'C' seam.)	*Coal* 18 ft. approx. (Bahira '5' seam.)

From the evidence of the Digari-Sabanpur bore-holes, the sandstone strata, which separate these two coal seams, vary somewhat in thickness, and the seams themselves are liable to local change. At Dendua and Salanpur collieries, the upper 'D' seam is reported to be of fair quality and slightly nodular, whilst portions of the lower 'C' seam yield a useful steam-coal. At Bahira, the upper '4' seam is of very good quality and with the lower seam '5' has been developed from the pits to the south-west of the village. Unfortunately, the seam '5' is, at its outcrop in the quarry south-west of Chanpataria, and within certain of the Digari-Sabanpur bore-holes, intersected by mica-peridotite sills and partially converted into *jhama.*

These two coal seams continue to crop out north-eastwards *via* Chanpataria, adjoining the south-westerly continuation of the Dendua cross-fault. The writer suggests that they are again met with dipping eastwards within the faulted area, near Digari, where they are intruded by mica-peridotite. The section given at the colliery just west of Digari included :—

	Ft.
Coal seam	9
Sandstone	22
Coal seam	18

The lower seam probably crops out again at the colliery inclines just south of Sabanpur village, the section here being reported as :—

	Ft.
Inferior *coal* and shale	2
Coal	10 to 11
Inferior *coal*	7 to 8

These workings appear to be cut off a short distance to the east by the fault that runs east of Bahira village. It is probably the same coal seam that has been worked in the past from inclines about three furlongs north-east of Salanpur village.

iv. Chanpataria shales and sandstones.

For the sake of correlation with the more western areas, these beds have been grouped in a separate stage. In this area they include only about 100 feet of sandstone and shale strata, intervening between the thick Bahira '1 to 3' coal seam and Bahira '4' seam, and crop out in the low ground below Bahira and Chanpataria villages.

v. Upper Bahira coal measures.

Bahira '1 to 3' seam.

These beds include the thick Bahira coal seam '1 to 3' undoubtedly equivalent to the Laikdih of the west, though definitely inferior to it both in quality and in thickness. The seam, however, contains workable sections of good coal, which have been developed in the past at Bahira colliery. The beds crop out in the form of an arc, just north and west of Bahira village, dipping gently southwards. To the north-east of the village they appear to be cut off by a fault, and a half to three quarters of a mile to the west, swing round to the south-west and south against the large cross-fault that separates the Bahira and Lalbazar areas. As at Lalbazar colliery, the seam includes three sections, which, in the old quarry workings a little over half a mile west-south-west of the village, comprise the following succession:—

(Soft grey sandstones).
Coal 3½ to 4 ft. (Bahira '1' seam); including bands of bright and dull coal.
Grey carbonaceous shales and sandstones 8 ft.
Coal 4 ft. 4 ins. (Bahira '2' seam); largely of bright coal.
Grey sandstones about 12 ft.
Coal with shale bands 18 ft. (Bahira '3' seam); base not seen.

Information obtained from the Bahira workings, (*see* Plate 16) indicates the following succession of coal seams to the dip:—

	Ft.	Ft. in.	
Coal	6 to	8 9	(Bahira '1' seam).
Coal	2 to	4 6	(Bahira '2' seam).
Coal	28 to	34 6	(Bahira '3' seam).

Massive sandstones with shale bands, overlie these Bahira coal seams, but about a quarter of a mile to the dip of their outcrops

are several old quarry-workings into a higher seam. This seam appears to occur about 100 feet above Bahira '1 to 3' seams, and is possibly about eight feet in thickness. No information was available regarding these old outcrop-workings, though the writer suggests that the seam may represent the easterly continuation of the Ramnagar seam. Its extent, as also that of the underlying coal seams, is, however, interrupted to the south by the north-easterly continuation of the Begunia-Petana strike-fault.

The strata of stage (vi), fail to crop out to the south of the Bahira area on account of the above-mentioned strike-fault. They are, however, questionably represented, in part, to the north of Rampur colliery.

vii. Rampur coal measures.

As in the case of the strata of stage (vi) these beds, including the equivalent of the Begunia coal seam, are cut out to the south of the Bahira workings by the north-easterly continuation of the Begunia-Petana strike-fault. To the south of this strike-fault, however, the topmost beds have been proved, though over the greater part of this area they are covered by varying thicknesses of Ironstone Shales. Subsidiary faults appear to complicate this area. The Begunia seam has been proved in depth to be of the order of five to six feet thick, and of good quality. The seam has, therefore, decreased in thickness very considerably as compared with the more western parts of the coal-field. This diminution in thickness appears to continue eastwards, for it is probably the easterly extension of the same coal seam that is met with at Rampur colliery, where the thickness is about 4 ft. to 4 ft. 6 ins. A second strike-fault probably runs to the south of this colliery, and small mica-peridotite intrusions apparently affect the present workings.

Begunia seam.

ALKUSHA-DHARMMA *NALA* AREA.

Within this tract is included the disturbed strip of lower Barakar measures running east of the cross-fault that separates the Banbirdi-Alkusha area, as far east as the parallel cross-fault that divides the Shyamdi workings from those between Mutachandi hill and Dabar village; together with the middle and upper Barakar rocks that crop out south of

Structure.

Dhundabad and Phulberya on either side of the Dharmma *nala*. Unfortunately, on account of the paucity of connected outcrops, and of the almost total absence of bore-hole and colliery information, the detailed lithology and structure of these latter southern areas remains, in a large degree, unsolved. The general dip of the measures is to the south and south-south-east at angles varying from 10° to 20°. At least one large cross-fault, following a north-easterly trend, traverses these lower Barakar rocks just east of Alkusha, but it is probable that other dislocations complicate the succession, though it is impossible to follow them with any degree of certainty. These lower measures have been the site of immense ultra-basic sill-intrusions, covering large areas around Mutachandi hill.

Tentatively, the Barakar measures of this area have been sub-divided as follows:—

iv to vii. Upper and middle Barakars of the Phulberya and Khudka area.
iii. Dhundabad-Mutachandi grits.
ii. Alkusha-Radhaballavpur coal measures.
i. Radhaballavpur conglomerates.

Details of the various stages are as follows:—

i. Radhaballavpur conglomerates.

These basal pebble-bearing strata crop out in the stream-section just north of Alkusha and are again represented in the higher ground half a mile south of Dabar. Within the lower portion of this stage a 3-foot seam of coal and carbonaceous shale (the Farewell seam) is noted in the stream north of Alkusha.

ii. Alkusha-Radhaballavpur coal measures.

Salanpur 'A' seam.

These beds include the easterly continuation of the thick Salanpur 'A' seam. The seam, however, appears to have decreased in quality and at least the upper part contains a large proportion of shale and shaly coal. It forms a wide outcrop across the Dharmma *nala*, intruded into by sills of mica-peridotite at the southern end of Alkusha village, and has been worked in the past in several quarries. This outcrop is limited by the large cross-fault that runs a short distance east of the village and throws the seams northwards to the workings of East and South Salanpur and Radhaballavpur collieries about half a mile south of Dabar village. The thick seam appears to have split

up within this area and in the western collieries includes in descending order :—

	Ft.
(Coarse grits with fireclay bands.)	
Coal with shale and fireclays above, total	8
Coarse grey sandstones	30 to 50
Coal, including shale bands, total	40 to 45

At Radhaballavpur colliery, just west of the cross-fault, which limits this area to the east, the section includes in descending order :—

	Ft.
(Coarse grits with fireclays).	
Coal and shale, about	10
Sandstones with shales, about	10
Coal and shale	40 to 45
Grey sandstones with basal band of grey shale . .	13
Coal seam	9 to 10
(Basal conglomeratic sandstones—stage i).	

The thick 45-foot seam has been quarried in the past, but these workings are now flooded. Attention was, at the time of the writer's visit, being paid to the upper coal seam and overlying fireclay beds. The latter appeared to be of very good quality. All the workings were confined to near the outcrop. At Radhaballavpur colliery the lower 9- to 10-foot seam was being worked from inclines. It is doubtful whether this seam should be regarded as the lower portion of the thick seam, separated by a local development of sandstone, or whether it would be found to continue laterally as a separate seam beneath this thick seam of coal and shale. This lower seam appeared to be of fairly good quality and to include :—

Lower seam at Radhaballavpur.

	Ft.	in.
Streaky, dull and bright *coal*	4	6
Hard dark grey shale containing iron pyrites	1	0
Streaky, dull and bright *coal*	4	0

The inclination of the strata is of the order of 12° to 20° to the south; whilst the coal seams are, in places, affected by mica-peridotite intrusions.

iii. Dhundabad-Mutachandi grits.

It is suggested that the massive sandstones and grits of the Dhundabad area, to the south of Alkusha, and recurring north-eastwards in the Mutachandi hill tract, should be correlated with those

of stage (iii) to the west. Among these beds a coal seam, intersected by mica-peridotite, is observed in the Dharnuna *nala* section at the right angle bend to the east of Dhundabad. No detailed sections of the succession of this stage are, however, available, and although it is more than probable that several coal seams are included within these massive grits, it is suggested that on account of the prevalence of mica-peridotite sill-intrusions, they may be found to be considerably damaged.

iv to vii. Upper and middle Barakar measures of the Phulberya-Khudka area.

This extensive tract of middle and upper Barakar rocks is to a large extent covered by paddy fields, with intervening patches of moorland. The Dharmma *nala* section is, unfortunately, incomplete. Within this area we should expect the easterly continuation of the thick upper Bahira seam and the Begunia-Rampur coal seam. It has been noted that these seams appear to show a decrease in thickness when followed eastwards from the areas adjoining the Barakar river. To what extent this change has continued within the Dharmma *nala* tract it is, without the evidence of bore-holes, impossible to decide. One or two deep borings, located within the upper measures east of Khudka or south of Phulberya, would be invaluable in solving this problem. It is possible that the old incline and shallow pit-workings just south of Khudka were into the easterly continuation of the Rampur seam. No information is, however, available regarding this solitary disused working.

Lack of information.

NANDAI-SHYAMDI-BALIAPUR AREA.

This easterly continuation of the Alkusha-Phulberya tract of Barakar strata, stretching from the longitude of the Radhabailavpur cross-fault eastwards to the large Itapora-Panuria fault, forms the connecting link with the Gourangdi portion of the coalfield to the north-east. Within this tract, the lower Barakar coal and fire-clay seams have been exploited at and near their outcrops in the vicinity of the Nonia *nala*; but like the area to the west, the higher measures are undeveloped and, on account of the lack of connected outcrops and of the total absence of bore-hole records, it is impossible to dogmatise on the detailed geology and structure. Several small outcrops of coal, often shaly, do occur among the sandstones, and

as is normally the case, these may be found to increase very considerably in thickness and to be of superior quality underground.

The lower Barakars of this area are affected by several cross-faults, but the principal dislocations are two roughly parallel strike-faults, which, running approximately east-north-east within the area north of Shyamdi and just south of Paharpur, cause the repetition of the basal thick seam of shale and coal.

Repetition of faulting.

The inclination of the beds, in general to the south or south-south-east, usually varies from 5° to 20°, but in the vicinity of the faults a steeper dip is sometimes recorded.

The Salma dolerite dyke traverses the measures *via* Nandai and Baliapur and a number of mica-peridotite dyke and wide-spread sill-intrusions occur, mainly within the lower half of the series.

Intrusions.

For the convenience of description, the measures of this area have been divided as follows :—

iv to vii. Upper and middle Barakars of the Parbbatpur-Amlala area.
iii. Shyamdi-Amdiha-Itapora grits.
ii. Paharpur-Alipur coal measures.
i. Nandai conglomerates.

The details of these various stages, roughly equivalent to those of the west, are as follows :—

i. Nandai conglomerates.

These basal, boulder-bearing, felspathic sandstones are well exposed in the tributaries of the Nonia *nala*, south-east of Manahara, and a short distance west of Nandai. Their repeated outcrops are well observed on the south side of the Nonia stream, south of Paharpur, and again just north of the same stream between the Lalganj-Panuria road and Alipur village. In both the Manahara and Nandai tributaries they include a thin 3-foot coal seam, doubtless the Farewell seam, and a distinct unconformity is observed between these pebble-bearing sandstones and the uppermost grey and orange, felspathic, soft sandstones of the Talchirs.

ii. Paharpur-Alipur coal measures.

These beds include the easterly continuation of the thick Salanpur 'A' seam, the outcrop of which is demarcated to the west of the Salma dyke by a number of old quarry-workings bordering the Nonia stream. At

Salanpur 'A' seam.

least in the eastern part of the tract, this thick seam is composed largely of black shale and shaly coal, with included ironstone bands. The basal beds immediately below this thick seam are well exposed in the vicinity of the junction of the three tributaries south-east of Manahara, where the following section is observed in descending order :—

	Ft.	in.
(Lower part of thick *coal* seam)		
Yellow-grey, felspathic sandstones	3	0
Fireclay, including 9 ins. of *coal*	3	0
Grey sandstone with some shales	35 to 40	0
Coal	1	6
Coarse, grey sandstones with coaly intercalations, about .	15	0
Shaly *coal*	3	0
(Pebbly sandstones of stage i, including numerous rounded quartzite boulders.)		

The outcrop of this thick seam appears to run west-south-westwards in the low ground to the north of Shyamdi colliery, some of the workings being apparently intercepted by the strike-fault, which roughly follows the seam outcrop. A shaft, put down near the chimney, which is indicated on the 4-inch sheet (No. 8) just south of Karkanali, was reported to have reached to a depth of 237 feet and to have passed through the following strata :—

Shaft near Shyamdi.

	Ft.	in.
Earth	10	0
White sandstone	20	0
Shale	4	0
Inferior *coal*	12	0
Shale	5	0
White sandstone	21	6
Coal	6	6
Sandstone	7	0
Shale and *coal* with 2 ft. sandstone in the middle . .	14	0
Sandstones	27	6
Coal	0	6
Sandstone and shale	22	0
Shaly *coal* and shales	5	6
Sandstones and shales alternating	31	0
Coal	4	0
Grey sandstones and shales	11	0
Coal	8	6
Shale	2	6
Shaly *coal*	2	0
Jhama	1	6
Shale	1	0
Coal	2	0
Shale	1	0
Coal	6	0
Shales and *coal*	10	6

The alternating coal, shale and *jhama* of the base of this shaft evidently represents the upper portions of the thick seam, though apparently most of the coal was of an inferior quality. The fireclays above this seam were being worked north of Shyamdi village.

Again, around Paharpur on the north side of the Nonia Jor, the thick coal and shale seam has been quarried in the past. This outcrop is cut off to the south by the second strike-fault and is repeated in the old workings north of Pahargora and Mohanpur. These workings were all closed at the time of the writer's visit though the fireclays, 5½ feet thick and associated with the seam of coal that overlies the thick seam, were being developed.

Workings at Paharpur and Pahargora.

Further east, where the Salma dyke crosses the Nonia, this thick seam is well exposed and includes black shale and shaly coal, with intervening bands of ironstone and shaly sandstone, making a total thickness of about 100 feet. The dip varies from 25° to 35° to the south-east.

East of the cross-fault, which follows near the Lalganj-Panuria road, it is probable that this thick seam of shale and coal would be met with beneath the alluvium a short distance south of the Nonia stream. Faulted to the north, it recurs between the two cross-faults a short distance south-west of Alipur village.

iii. Shyamdi-Amdiha-Itapora grits.

It is suggested that the massive sandstone and grit beds of the Shyamdi-Amdiha-Itapora tract are equivalent to those of Dhundabad and Mutachandi hill to the west, and are represented in the Panuria area by the Gourangdi grit and coal measures. On this assumption, we should expect to find at least one coal seam of appreciable thickness among these measures, though whether it would be equal in thickness and quality to the main Gourangdi coal seam is impossible to say. The absence of coal-outcrops within this stage may well be explained by the creep of the associated massive grits and the occurrence of a superficial covering of soil within the intervening tracts. Borings to the dip, say near Parbbatpur or Bila village, might well result in the discovery of coal of workable value.

Absence of coal-outcrops.

A short distance north of Mohanpur village, a seam had been proved among the sandstone strata and was reported to include:—

	Ft.	in.
Coal	2	6
Band	0	3
Coal	6	3
(Fireclay.)		

Mica-peridotite sill-intrusions occur within the strata of this stage, to the west of Itapora and Amdiha.

iv to vii. Upper and middle Barakars of the Parbbatpur-Amlala area.

As in the vicinity of the Dharmma *nala* to the west, it is impossible to define the various stages of this area. One small working into what appears to be a seam of shaly coal, is observed about half a mile south-east of Shyamdi. The evidence of the diminution in thickness and the decline of quality of the coal seams of these measures as they are followed eastwards from the Lalbazar-Begunia tract into the Bahira-Rampur locality, and again, the lack of thick workable seams within these upper and middle measures of the Gourangdi-Jamgram area to the north-east, inclines one to the view that these equivalent beds, between the Dharmma *nala* and the Panuria-Itapora cross-fault, may prove relatively unproductive. A thick seam of shaly and inferior coal, and an upper 6-foot seam of better quality, have, however, been proved within the equivalent measures of the Jamgram area, and it is reasonable to suppose that these two coal seams may be represented, perhaps in greater thickness, in the area under consideration.

III.—Gourangdi-Churulia area.

This area of Barakar rocks includes the colliery districts of Gourangdi, Kantapahari, Jamgram, Sarshatali, and Churulia. With the exception of the latter, these extensive workings are now closed. The general strike of the beds is to the east-south-east, but in the approach to the main Panuria-Itapora cross-fault, which limits the area to the west, the strata swing round to the south-west and south obliquely parallel to the displacement, and the dip, which is normally of the order of 10° to 20°, increases locally to as much as 45°. A number of other faults intersect the area, the most important being the Sarshatali-Madanpur oblique-fault;

Structure.

this displacement also locally affects the inclination of the beds. To the north of Panuria, the basal pebble-bearing Barakar sandstones rest on the uppermost Talchirs, but further east these beds are overlapped and the Barakars immediately overlie the mica-quartz-schists of the Archæans. Devoid of dolerite intrusions, the lower measures form the site of wide-spread mica-peridotite sills,

Intrusions.

which affect the basal seam to the north of Gourangdi and occur more regularly across the massive sandstones of the Sarshatali-Churulia tract.

For the purpose of description the region has been sub-divided into the following three areas (*see* Table 5):--

1. **Ramdhara-Panuria area.**
2. **Kantapahari-Jamgram area.**
3. **Sarshatali-Churulia area.**

The details of these various areas are as follows:---

RAMDHARA-PANURIA AREA.

The Barakar measures of this area are intercepted to the west by the large Panuria-Itapora cross-fault. East of this displacement, the measures crop out in an irregular synclinal pitching to the south-east. The dips in the western limb of this synclinal adjoining the main fault are steep, the beds being locally crushed and, apparently, affected by several subsidiary displacements. As a result of these complications, combined with a lack of reliable bore-hole and colliery records (the workings now being closed) the detailed structure of the upper measures, which adjoin the fault, remains doubtful.

For the purpose of correlation and convenience of description, the Barakar measures of this area have been divided into the following stages roughly equivalent to those of the west:—

- **vi and vii. Upper Barakar measures.**
- **v. Upper Gourangdi coal measures.**
- **iv. ? Sandstones and shales.**
- **iii. Main Gourangdi grit and coal measures.**
- **ii. Ramdhara coal measures.**
- **i. Kasidhara conglomerates.**

The detailed lithology of these various stages is as follows:—

i. Kasidhara conglomerates.

These pebble-bearing sandstones, characteristic of the base of the Barakar measures, are well-exposed in the higher ground around Kasidhara village and east-south-eastwards to the north of Panuria,

TABLE 5.—*Gourangdi-Churulia and Trans-Adjai areas.*

(4-inch sheets Nos. 7, 11, 12 and 16.)

STAGE.	RAMDHARA—PANURIA AREA.	KANTAPAHARI—JAMGRAM AREA.	SARSHATALI—CHURULIA AREA.	TRANS-ADJAI AREA.
vii. vi.	Upper Barakar succession uncertain, on account of strike faulting.	Upper sandstones and shales with thin coal seams.	Sandstones and shales . .	Sandstones and shales with thin coal seams.
v.	? Upper Gourangdi coal measures	Upper Kantapahari—Jamgram coal measures.	? Jaynagar shales.	
iv.	? Sandstones and shales . .	Sandstones and shales . .	Sandstones and shales.	
iii.	Main Gourangdi grit and coal measures.	Main Kantapahari—Jamgram grit and coal measures.	Main Churulia grit and coal measures.	Kasta grit and coal measures.
ii.	Ramdhara coal measures . .	Lower Kantapahari—Jamgram coal and shale measures.	Lower Churulia shale and coal measures.	Kharimati sandstones and shales with thin coal seams.
i.	Kasidhara conglomerates . .	Jamgram conglomerates . .	Thin basal conglomerates . .	Thin basal pebbly sandstones.
(TALCHIRS)			(METAMORPHICS)	

ii. Ramdhara coal measures.

Undoubtedly the easterly continuation of the Salanpur 'A' coal measures, these strata include a seam of black shale and shaly coal, said to attain a total thickness of at least 60 feet. The outcrop of this seam occupies the low ground to the dip of the Kasidhara ridge. The included coal bands are reported to be of unworkable quality and are in addition intersected by mica-peridotite sill-instrusions.

iii. Main Gourangdi grit and coal measures.

Coarse sandstones and shales with good quality fireclays, overlie the Ramdhara seam and are comparable to the corresponding sequence of the more western areas. Near the top of this succession, massive sandstones include the 19- to 20-foot main Gourangdi seam. The actual outcrop of this seam is observed along the top of the ridge about half a mile north of Gourangdi railway-station; it is apparently burnt, as is evidenced by the indurated, bleached and reddish, brecciated shales and sandstone fragments that cover the surface. A short distance to the dip, the seam has been worked from a number of inclines and shallow pit-workings, and from quarries located at the eastern end of the ridge. The lower 7-foot portion of the seam was apparently of good workable quality. The outcrop is interrupted by faulting near the eastern end of Panuria village.

Gourangdi seam.

iv. ? Sandstones and shales.
v. ? Upper Gourangdi coal measures.

To the dip of the inclines into the main Gourangdi seam is a succession of sandstone and shale strata of the order of 200 feet thick. These outcrops are followed to the south by a coal seam, the workings of which were, unfortunately, closed and flooded. It was suggested by certain people, who were acquainted with the past mining of the area, that this second seam represents the main Gourangdi seam repeated by faulting. Unfortunately, no plans were available to corroborate this suggestion. From the general lithology and structure, as determined by the surface exposures, the writer was inclined to regard this upper seam as equivalent to the upper Kantapahari-Jamgram seam, a seam of inferior quality some 15 feet thick.

Second seam at Gourangdi.

vi and vii. Upper Barakar measures.

Upper Barakar measures doubtless crop out within the tract south of Panuria. They appear, however, to be much disturbed by faulting. Several coal seams up to as much as nine feet in thickness have been proved by bore-holes, within these alternating sandstone and shale strata. These have been exploited to a small extent in the past from several inclines.

KANTAPAHARI-JAMGRAM AREA.

This tract of Barakar rocks stretches east-south-east of Panuria as far as Sarshatali where the strata are interrupted by the Sarshatali-Madanpur cross-fault. The area is somewhat disturbed by other oblique cross-faults and, east of Jamgram, two prominent sills of mica-peridotite intersect the basal and the middle Barakar horizons, probably following the lines of outcrop of the coal seams. The strata of this area have been divided into the following equivalent stages:—

Faults and intrusions.

vi and vii. Upper sandstones and shales with thin coal seams.
v. Upper Kantapahari-Jamgram coal measures.
iv. Sandstones and shales.
iii. Main Kantapahari-Jamgram grit and coal measures.
ii. Lower Kantapahari-Jamgram coal and shale measures.
i. Jamgram conglomerates.

The details regarding these stages are as follows:—

i. Jamgram conglomerates.

These basal pebble-bearing Barakar sandstones, somewhat thinner than to the west, are exposed in the wooded tract about five furlongs north of Kantapahari. They continue east-south-east, resting on the metamorphics just north of Jamgram village and further east as a relatively thin band in the ridge west of Sarshatali foundry. Grey carbonaceous shale and fireclay bands are included in the uppermost sandstones.

ii. Lower Kantapahari-Jamgram coal and shale measures.

These beds include the thick seam of shale and inferior quality coal, of the order of 35 to 40 feet thick, which intersects the large tank just north of the Panuria road, half a mile north of Kantapahari. The seam apparently continues eastwards in the low ground north of the railway and is seen to crop out again just north of the line to the west of Sarshatali foundry.

Equivalent of Salanpur 'A' seam.

From a comparison of the lithological sequence, this seam appears to represent the thick Salanpur 'A' seam of the west, though it is of a considerably decreased thickness and of very inferior quality.

iii. Main Kantapahari-Jamgram grit and coal measures.

The strata of this stage, overlying the basal thick seam of shale and shaly coal, include a succession of sandstones with iron-stones at the base, followed above by massive sandstones with good quality fireclays intercalated. At the top of the sequence, the 20-foot Gourangdi-Jamgram coal seam is met with. The outcrop of this seam is, in the area north of Kantapahari, marked by a number of large quarry and incline workings, all of which, together with the shaft-workings to the dip, have been closed for some years. A fine section of the burnt outcrop of the seam, represented by white, cream-coloured and reddish clay shales, is exposed in one of these inclines on the hillock, about a quarter of a mile north of Kantapahari. The fireclays, which occur below this seam, and which crop out to the north of the railway, are now being exploited. Interrupted by several minor cross-faults, the coal seam continues in the northern quarry-workings of the Jamgram area, in the vicinity of the railway-line.

Jamgram seam.

About half a mile east of Jamgram village, just north of the railway, two closely-associated rows of inclines mark the outcrop of coal seams associated with similar grits and fireclays as those belonging to the stage under discussion. Further east it is suggested that these strata continue just south of the railway, the outcrop of the main seam being probably located about 220 yards from the line. The strata of this stage, as here represented, are considerably thinner than those of the western portions of the coalfield, being about 200 feet thick.

v. Upper Kantapahari-Jamgram coal measures.
iv. Sandstones and shales.

Alternating massive sandstones and shales, of a total thickness of from 200 to 220 feet, overlie the main Kantapahari-Jamgram seam, and are followed by a second thick coal seam. This seam is reported to be from 15 to 20 feet in thickness and in one bore-hole a total of 27 feet is recorded. Much of this total thickness apparently includes shale and shaly coal, and the seam was regarded as definitely inferior to the main Gourangdi-Jamgram seam. The outcrop of the seam is marked by a number of old inclines to the north of

Kantapahari and west of Jamgram. To the east of the latter village it does not appear to have been exploited.

vi and vii. Upper sandstones and shales with thin coal seams.

The upper measures of this area, exposed at intervals around and to the south of Kantapahari village and also south of Jamgram, include a succession of sandstone and shale strata with several thin coal seams, of which at least one is of workable quality. This seam has been exploited in the past near Kantapahari, and about half a mile south-east of Jamgram. It is reported to be from six to seven feet in thickness and to include:—

Seam in the upper Barakar measures.

	Ft.	in.
Coal	4	6
Band, about	1	0
Coal	1	2

SARSHATALI-CHURULIA AREA.

This area includes the strip of Barakar measures striking south-eastwards, to the east of the Sarshatali-Madanpur fault, *via* Churulia, to the Adjai river, where the beds are intercepted by the Adjai river fault. Except in the vicinity of these two limiting displacements and of the minor cross-faults, which intersect the area, the inclination of the strata is of the order of 15° to 25° in a S. 30° to 35° W. direction. Mica-peridotite sill-intrusions cover wide areas of the basal measures between Churulia and Sarshatali. Throughout this area the basal Barakar measures, considerably thinner than in the western parts of the coalfield, rest directly on the metamorphics.

Structure.

The strata of this area have been divided into the following stages:—

vi and vii. Sandstones and shales.
v. ? Jaynagar shales.
iv. Sandstones and shales.
iii. Main Churulia grit and coal measures.
ii. Lower Churulia shale and coal measures.
i. Thin basal conglomerates.

The details of these various stages are as follows:—.

i. Thin basal conglomerates.

These basal Barakar beds, diminutive representatives of the thick pebbly sandstones of the west, include a thin sequence of yellow felspathic, and reddish ferruginous sandstones, within the base of

which a few quartzite pebbles are occasionally observed. They crop out just beyond the base of the Sarshatali scarp, and are again well exposed in the approach to the Adjai river a short distance west of Deshermohan.

ii. Lower Churulia shale and coal measures.

The thick basal seam of shale and coal continues within this area, cropping out in the Sarshatali area at the base of the sandstone—mica-peridotite ridge to the north-east of the foundry. The seam has been proved in several small surface workings. From a comparison of the lithology of the basal Barakar measures, the writer suggests that it is the south-easterly continuation of this coal seam, possibly locally improved in quality, which has been quarried at Garh Dhemo colliery to the south of Andhaira. The total thickness of the seam is reported to be about 34 feet, and includes in descending order:—

Garh Dhemo seam.

(Sandstone.)	Ft.	in.
Coal	1	6
Shale	0	10
Coal	1	10
Shale	0	8
Coal	11	6
Shale	0	9
Coal	1	0
Shale	0	3
Coal	6	0
Shale	3	0
Coal	2	0
Shale	0	6
Coal	4	0

The 11 ft. 6 in. section of the seam had been worked, and included mainly dull coal, low in volatiles. Much of the coal of this seam is of relatively inferior quality.

The same coal seam probably crops out near the base of the Barakar measures in the cross-faulted tract to the south-east, its outcrop being represented by dark carbonaceous fireclays. It recurs again, as a wide exposure, a short distance north of the railway, in the *nala*-section about five furlongs north-west of Churulia station. A similar seam was reported to have been proved within the basal measures, adjoining the railway to the north-east of the present Churulia colliery, and probably continues within the old inclines

Basal coal seam near Churulia.

located on the north-east side of the railway, a short distance further south-east. In the area towards Deshermohan, occasional outcrops of black shale probably denote the extension of the seam towards the Adjai river.

Within this Churulia-Deshermohan tract, good quality fireclays are associated with the massive sandstone strata below this coal seam. These were being worked at the time of the writer's visit.

iii. Main Churulia grit and coal measures.

Within the Sarshatali-Churulia tract, massive hard sandstones, with associated thin seams of fireclay, overlie the basal coal and shale horizon. These beds compare well with those of the Gourangdi-Jamgram area. In the vicinity of Churulia colliery, the main Churulia seam is included at the top of these measures, and is worked from a number of inclines. To the north-west of Churulia, this seam does not appear to have been proved. The writer suggests that it is represented, in the low ridge just west of Churulia station, by a burnt outcrop, and that it continues further north-west in the low ground at the foot of the dip-slopes of massive sandstones that constitute the Sarshatali-Garh Dhemo ridge. It is quite probable that the mica-peridotite sill-intrusions, which are so widespread within the latter tract, have considerably damaged the coal seams.

Main Churulia coal seam.

At Churulia colliery this main seam, dipping S. 40° W. at 16°, includes a total thickness of 34 feet. The upper and middle sections of the seam are comprised of alternating bands of shale and coal, the basal 7- to 8-foot section alone being worked. The area is intersected by several small faults and mica-peridotite intrusions.

vi.—vii. Sandstones and shales.
v. ? Jaynagar shales.
iv. Sandstone and shales.

Massive sandstones, shaly sandstones and shales, with bands of ironstone overlie the main Churulia seam. No records are available denoting the occurrence of important coal seams within these higher measures, though, from a lithological comparison with the more western tracts and the Trans-Adjai field to the north-east, at least several relatively thin seams are to be expected. An outcrop of a thick seam of carbonaceous shales with ? shaly coal, running west-

Absence of coal in upper measures.

north-west of Jaynagar village, possibly represents the line of the *upper* Kantapahari-Jamgram seam.

IV.—Trans-Adjai area.

Distribution of measures.

This area of Barakar measures to the north of the Adjai river fault forms a relatively narrow tract stretching continuously from near Pariarpur in the north-west to the approach to the Hingla river in the south-east. In the vicinity of the Hingla, this continuity of outcrops is broken, but to the north-east of the river the basal Barakars recur as a number of outliers resting on the underlying metamorphic rocks. The higher Barakar measures are hidden throughout this tract, in the north-west by the river-sand of and adjoining the Adjai river, and further south-east by alluvium, which covers a wide area to the north of the Adjai, so that in no instance is the passage up into the basal Ironstone Shales exposed. At least in the case of the north-west portion of this Trans-Adjai field, these Barakars show distinct resemblances to those of the Churulia area, with which they were doubtless closely connected during the period of deposition of the sediments. As might be expected, the basal coal and shale seam of the Churulia area—representative of the Lower Salanpur coal measures of the west—appears to have almost died out, but the equivalent of the main Gourangdi-Churulia coal seam is well represented within the Pariarpur-Arang tract and includes a workable section of good quality coal, rendering the area of considerable economic importance. This coal seam decreases in thickness, steadily, to the south-east of the Kasta area, and beyond Arang it has, so far, proved of little economic value.

Correlation with the Churulia area.

Structure.

The general inclination of the strata is to the S. 20° to 35° W. at angles varying from 20° to 30° in the Pariarpur-Arang area, whilst further east the dip is more southerly and gentler inclinations prevail. In the vicinity of the several dip- and strike-faults, which intersect the measures, steeper dips are recorded.

Intrusions.

Unlike the Barakar areas to the south of the Adjai river, this Trans-Adjai field is singularly free from intrusions. No dolerite dykes are met with and only in the vicinity of Arang and Parsundih are small dyke- and sill-outcrops of mica-peridotite type observed.

For the convenience of description the Trans-Adjai field has been divided into the following three areas :—

1. Pariarpur-Parsundih area.
2. Afzalpur-Raswan area.
3. Hingla river-Khayrasole area.

The details of the Barakar measures of these various areas are as follows :—

PARIARPUR-PARSUNDIH AREA.*

This area includes all the important collieries of the Trans-Adjai field. These comprise the workings of Pariarpur, Kasta, Sultanpur, Jarkunri (Jorkuri), Karabad and Arang. The lower Barakar measures, normally overlying the metamorphics, are well exposed in and adjoining the several deep cuttings of the railway that traverses the area. To the dip, the higher measures are exposed at intervals up to within a short distance of the Adjai river, and the sections of the several bore-holes, which have been put down near the left bank of the river, (*see* Plate 16, bore-holes 14 to 19) give a very clear idea of the sequence of these lower and middle Barakar beds down to the horizon of the main 'Kasta' coal seam.

For the purpose of correlation with the areas south of the Adjai, the strata of this Trans-Adjai tract have been divided into the following, corresponding stages (*see* Table 5) :—

- iv to vii. Sandstones and shales, with thin coal seams.
- iii. Kasta grit and coal measures.
- ii. Kharimati sandstones and shales, with thin coal seams.
- i. Thin basal pebbly sandstones.

Several dip- and oblique-faults complicate the strata of this tract and limit the above-mentioned colliery areas. Several strike-faults have also been met with in the present colliery workings, but usually, on account of the normally fairly steep inclination of the beds, these are difficult to locate on the surface. One important strike-fault, however, running between the Kasta and Sultanpur collieries and the railway-line is well exposed and causes the repetition of the basal measures up to the horizon of the main Kasta seam. A narrow exposure of

Faults.

* On the 4 inches to one mile sheet (No. 11), an inlier of metamorphic rock has, in the process of printing, been incorrectly demarcated within the Kasta railway-cutting. The boundary of this 'inlier', in reality, represents a thin coal seam cropping out from within the Barakar measures, which rocks are exposed throughout the whole of the cutting.

metamorphic rocks is observed separating these two repeated outcrops to the north of Kasta colliery.

The details of the above-mentioned stages are as follows:—

i. Thin basal pebbly sandstones.

It is possible that these lowermost sandstones, with occasional small pebbles of vein-quartz at the base, represent a slightly higher horizon than the thick basal conglomerates of the western portion of the Raniganj field. These sandstones are usually of a medium texture, and of yellow-grey to reddish tints; they are often shaly, and include bands of sandy and argillaceous ironstone. The lithology of the beds suggests that they have largely been derived by the erosion of metamorphic rocks of types similar to those upon which they have been deposited, and in the case of some of the more weathered outcrops, the exact junction with these metamorphic rocks can only be determined with difficulty. These basal beds are well exposed in the several railway-cuttings, in particular just north of Jarkunri.

ii. Kharimati sandstones and shales with thin coal seams.

These strata crop out above the basal pebbly sandstones, except in the Jarkunri-Karabad area, where they appear to be partly eliminated at the surface by strike-faults, questionably of the reversed type. They include massive sandstones, shaly somewhat ferruginous sandstones and shales, with at least one thin seam of shale and shaly coal. This seam has been proved in a small working just south of Kharimati Rampur, and probably occupies the low ground across the cross-fault, to the east-south-east of that village. These beds are poorly representative of the equivalent stage of the areas south of the Adjai, and point to the fact that the conditions that resulted in the formation of the thick Salanpur 'A' seam of the middle portion of the coalfield had almost completely died out within these north-eastern tracts of sedimentation. Thin seams of fireclay are associated with the strata of this stage.

iii. Kasta grit and coal measures.

These coal-bearing beds, very similar in type to the Gourangdi and Churulia grits and coal measures, include a succession of massive and shaly sandstones with bands of shale, and at least two seams of grey fireclay. The main coal seam—the Kasta seam—occurs at the top of this stage.

Kasta seam.

From a detailed study of the lithological sequence and the geological structure, the writer has no doubt regarding the equivalence of this main coal seam of the various Trans-Adjai colliery areas within which it has been proved. With this conclusion Mr. Auden, who also visited several of these areas, is in agreement. This correlation is further borne out by a comparison of the bore-hole sections of the various areas. In the Pariarpur tract the seam is of a total thickness of nearly 40 feet. The upper half includes a number of shale bands, but the lower 14-foot section comprises good quality steam coal, and was being worked from the inclines of Pariarpur colliery. This portion of the seam is composed of a considerable proportion of dull coal—durain—alternating with thin bands of vitrain. Several oblique faults affect the outcrop of the measures within and around the colliery-workings. South-east of the colliery, the seam appears to continue, unaffected by any large displacements, *via* the Kasta inclines to Sultanpur colliery. Within these areas the seam is of the order of 34 ft. 6 in. thick, the lower 12- to 13-foot section being worked. Bore-holes to the dip have proved the seam to continue in thickness up to the Adjai river. To the north of the Kasta-Sultanpur tract, a thick coal seam is exposed in the flooded quarry-workings of Palasthali colliery and is probably represented further west by a burnt outcrop. The writer is of the opinion that this coal seam is the equivalent of the Kasta seam, repeated by the strike-fault that runs just south of these northern outcrops. The seam was reported to be about 32 feet thick, and is followed a short distance below by a second seam of shaly coal, said to be about 10 feet in thickness. Just east of Sultanpur colliery, the Barakar measures are thrown down to the north-east by a prominent cross-fault, and within the tract beyond this displacement, as far east as the Jarkunri *nala*, the seam is not exposed. From a comparison of the lithological sequence, however, the writer suggests that the Kasta seam will be met with among the measures a short distance south of the railway near Barkuri village.

Pariarpur-Kasta area.

Thick seam at Palasthali.

Within the Jarkunri-Karabad area, a portion of the strata of this stage appears to be cut out by strike-faulting, so that the Kasta seam crops out much nearer the metamorphics than within the more north-westerly parts of the field. At Jarkunri (Jorkuri) colliery the

Jarkunri-Karabad area.

seam included a total thickness of about 32 ft. 6 in. the following section being recorded :—

(Shaly grey sandstone—roof)

	Ft.	in.
Shale and shaly *coal*	4	4
Coal (of inferior quality)	8	0
Shaly *coal*	4	6
Coal	1	11
Shale	1	3
Coal (of fair workable quality)	12	6

The basal 12 ft. 6 in. section was being worked. A somewhat similar section is observed at Korabad colliery. The seam, therefore, shows a distinct tendency to decrease in thickness, and as a whole to decline in quality to the south-east, and this change is further evidenced within the Arang area. Here the Kasta seam is reported to be about 28 feet thick, of which only the lower 8 ft. 6 in. section is of present workable value. Further east, to the north-west by west of Parsundih, borings to the dip record a total thickness of shale and coal up to 28 feet, though from the evidence of the abandoned incline-workings, this seam appears to thin considerably in the vicinity of its outcrop. A prominent cross-fault interrupts the Barakar measures to the north-west of Parsundih and causes the local steepening of the dips and the probable attenuation of the included coal seam.

Arang-Parsundih area.

iv to vii. Sandstones and shales with thin coal seams.

The strata overlying the Kasta seam are well illustrated in the several deep bore-hole sections referring to this area. Shaly sandstones and shales comprise the 200 ft. of Barakar beds immediately above these coal measures, but within the following sequence several thin coal seams are observed, among which a 5- to 6-foot seam is recorded. The highest beds represented appear to be entirely unproductive. The Ironstone Shales are hidden within the Pariarpur-Parsundih tract, so that it is impossible to say whether these uppermost measures include the highest horizons of the Barakar series.

AFZALPUR-RASWAN AREA.

This area has been mapped by Mr. Auden, from whose reports the following description is taken :—

'Only the lower Barakar measures are exposed, the higher stages being hidden beneath the alluvium, which stretches for some considerable distance north of the Adjai river. The succession of these lower Barakar beds is similar to that of the Pariarpur-Parsundih tract. Within this area the gradual overlap of the basal Barakars continues and their junction with the metamorphics is invariably marked by a zone of intermingled angular fragments and blocks of vein-quartz in a ferruginous grit or ironstone matrix.'

Basal Barakars.

Mr. Auden suggests that these quartz inclusions are derived from the numerous veins that intersect the adjoining metamorphics. To the north of the outcrops of this basal pebble-bed *in situ* are a number of outliers of loose gravel composed of similar fragments of vein-quartz, apparently residual to the basal Barakar beds, which, it is assumed, formerly continued northwards over an uneven metamorphic land-surface.

Resting on these basal consolidated quartz-breccias and conglomerates is a sequence of massive grits with fireclays near the base, and the main coal seam above. These beds are undoubtedly the representatives of the Kasta grit and coal measures of the north-west. Within the tract under discussion, the same tendency of this coal seam to decrease in thickness and deteriorate in quality when followed to the east-south-east, is well evidenced. No actual outcrop of coal is exposed and the scattered inclines and pits are all abandoned and collapsed. In the incline-workings of the Afzalpur locality, the seam is reported to be 11 feet in thickness, whilst at Raswan to the east, only six feet of workable coal is recorded. Fortunately, further information is available, three bore-holes having been put down through the higher measures to the horizon of this coal seam.

Kasta seam.

These include :—

(*a*) A bore-hole located on the south side of Raswan village, reported to have proved a seam of coal and shale of a total thickness of 21 feet at a depth of 323 feet.

(*b*) Two bore-holes located north and south of the railway to the south of Ujansuli village, proved 7 ft. 8 ins. and 8 ft. 6 ins. of coal respectively.

No details are available regarding the quality of the 21-foot seam of the Raswan bore-hole, though, since the seam has not been exploited for many years in spite of its close proximity to the railway, it is suggested that the coal is, at any rate to a large extent, either shaly or of an inferior grade. There is little doubt, however, that all these three thicknesses refer to one and the same coal seam, located within the basal Barakar measures, and it is more than probable that this seam represents the easterly continuation of the Kasta seam of the north-west.

Seam at Raswan.

Evidence of folding is noted within these lower measures of the Raswan locality, but towards the dip these folds probably flatten out long before the Afzalpur-Chhatrishganda fault is approached. The possibility of a fault bringing in the metamorphics near Hazratpur village is suggested, and any such dislocation would naturally limit the occurrence of these coal-bearing measures to the east.

From the evidence of the surface exposures, the higher Barakar beds overlying the coal seam include a sequence of sandy ironstones and shales, followed above by conspicuous massive grits alternating with bands of ironstone. These beds can be followed west of Barhra village to near Parsundih where they swing round to the south-east, almost parallel to the Afzalpur fault.

Higher Barakar measures.

HINGLA RIVER-KHAYRASOLE AREA.

East of the Hingla river up to a short distance east of Khayrasole, a strip of sediments, comparable in type to the lower Barakars of The Trans-Adjai area immediately to the west, crop out over a narrow tract, about 5½ miles in length. Of a maximum width of about one mile to the west, these outcrops narrow eastwards to only a quarter of a mile near Khayrasole village. The beds occur as an unsymmetrical synclinal, the axis of which follows a general east-south-easterly trend along the length of the tract, a short distance north of its southern boundary. This southern boundary follows a very direct trend and was regarded by Dr. Blanford as being represented by a strike-fault, which brought up the metamorphics to the south. Mr. Auden, however, is inclined to dissent from this view; he regards the supposition of a fault as unnecessary, and in support of this contention he notes that in the western part of the area the basal Barakars, dipping north-east at 26°, rest directly on the metamorphics with no sign of a disturbed junction.

Distribution.

Southern boundary.

The basal Barakar rocks of this area include a thin series of grits, in some places pebbly, with ironstones and bands of fireclay. In some instances, as near Panshuri village, the basal bed is a fireclay, followed by felspathic grit and ironstone above. Sandstones, associated with a seam of coal and shale, reported to be of a total thickness of 13 feet, overlie these basal measures, at an horizon comparable to that of the Raswan-Kasta seam of the west. This seam has been worked in the past at Gangpur and Bahadulch collieries, the coal being reported to be of an inferior grade. The higher measures, exposed within the wooded tract east of the Hingla river, include ferruginous grits with ironstones, some of which exhibit an oolitic structure.

Lithology.

V.—Area adjoining the Damodar river.

Within the Raghunathpur-Maluncha hill area, to the north and south of the Damodar river, a narrow strip of Barakar rocks crops out. These beds, which overlie the Talchir sediments to the north of the Damodar and transgress on to the metamorphics of the southern bank of the river, are limited by faults near Chakaltabari village further south-west. To the north-east, these measures are cut off by the large Patlabari-Deilya (Deoli) fault, but to the south-east, they grade up into shales with ironstones, representative of the Ironstone Shale series. In general, these Barakar beds dip regularly to the south-east at about 30°. Just north of the Damodar, the basal beds are well exposed, and include typical massive, yellow-grey, felspathic sandstones with rounded boulders of gneiss and quartzite, whilst in the southern bank of the river these included boulders are often sub-angular. Further south-west, beyond Maluncha hill, indurated blue-grey gritty fireclays overlie the metamorphics and, being somewhat shattered, the outcrops suggest the possibility of their being slightly overthrust across these underlying older rocks. In the vicinity of the Damodar, typical massive Barakar sandstones follow the basal pebble-bearing beds, and with these are associated bands of shale and fireclay, and at least one seam of coal. This coal seam is several feet in thickness at its outcrop, but considering the nature of the associated beds it is quite probable that the seam would be found to increase in thickness to the dip. Massive hard sandstones, alternating with shaly sandstones, continue above and are well exposed in the Maluncha hill area. They

Distribution.

Lithology.

include at least one seam of black shale (and possibly coal) exposed in a small flooded working a short distance north-east of the hill. The uppermost beds include massive sandstones alternating with shaly sandstones and shales, which, in the vicinity of Kelyasota and to the south-west, are observed to pass up into grey shales with ironstones and bands of sideritic sandstones. These uppermost Barakar measures grade upwards into dark-grey carbonaceous shales with ironstones, typical of the Middle Damudas. The topmost sandstones of the Barakar measures also pass laterally into shaly sandstones and shales, so that they crop out as lenticular-shaped hillocks among the softer shale strata. The passage from the Barakars up into the Ironstone Shales is, therefore, definitely transitional. Allowing an average gradient of 26°, the total thickness of these Barakar measures is of the order of 925 feet, showing a marked decrease as compared with the north-western portions of the coalfield. It is difficult to correlate these measures in detail with those of the northern Barakar areas. The conditions of sedimentation appear to have been somewhat different and, as has been previously mentioned, the sequence suggests the approach to the limits of deposition during Talchir-Barakar times. No colliery-workings exist within the area, so that no information is available regarding the nature of the coal seams in depth. It is quite probable, however, that at least the lower Barakar measures would repay investigation.

Passage up into Ironstone Shales.

Thickness of Barakars.

Summary of Correlation of Coal Seams.*

The summriased correlation of the coal seams of the Barakar measures is as follows:—

1. Pusai-Merthadih-Farewell seam.

This seam immediately underlies the conglomeratic sandstones of the basal Barakar measures. Including several shale and stone bands, the total thickness of the seam in the vicinity of the Pusai *nala* in the extreme north-west of the coalfield is of the order of 25 to 30 feet. It thins eastwards to about 20 feet at Khusori and then rapidly to five feet (?) in the flooded inclines near Merthadih village. Further east, it apparently continues as a thin seam of

* *See* Plate 16, and table of analyses on p. 272.

shale and coal beneath the very constant conglomeratic sandstone horizon. In these eastern areas it is popularly termed the Farewell seam, but is of no economic consequence. It is probably represented by carbonaceous shale bands in the Gourangdi area, and dies out a short distance further east. Even in the west of the field it is of relatively poor quality, consisting almost wholly of dull coal.

II. Lower Birsinghpur-Kalimati-Damagaria-Salanpur 'A'-Paharpur seam.

Almost immediately overlying the thick conglomeratic sandstones of the lower Barakar measures, on either side of the Barakar river, is the thick coal seam of Kalimati and Damagaria. Of a total thickness of at least 50 feet at Kalimati, it increases to over 100 feet at Damagaria. The lower part of the seam is of good workable quality, the upper portion being inferior and including bands of shale. Westwards and eastwards this seam decreases both in thickness and quality. West of the Kalimati fault, it is 40 and 35 feet at Egarcoor and Kapasara respectively, and probably splits up into several seams still further west. As such it is doubtless represented by the lower coal seams of the Birsinghpur stage at Khodo (Khoodia) colliery and by the lower seams of the Kanauri stage further west. East of the Barakar river, the Damagaria seam is represented in the Dendua-Bonjumari area by the thick Salanpur 'A' seam. Further east, it becomes distinctly shaly, but is exposed in the old outcrop workings of Banbirdi, Alkusha and Paharpur. In the latter area it is repeated by a strike-fault. Still further east, it can be followed as a thick seam of shale with bands of shaly coal, overlying the conglomeratic sandstones as far east as Alipur. Within the Gourangdi tract the seam, largely consisting of shale and shaly coal, decreases considerably in thickness, being about 35 to 40 feet at Kantapahari. In the Sarshatali-Churulia tract it appears to be represented by the 34-foot seam of Garh Dhemo colliery and of the old inclines just north-east of the railway to the south-east of Churulia station, whilst across the Adjai it has died out beyond recognition.

Salanpur 'B' seam.

In the Salanpur area a thin seam—Salanpur 'B'—said to be from 7 to 10 feet in thickness, overlies the Salanpur 'A' seam, the intervening strata being from 25 to 40 feet in thickness. A similar coal seam is met with in borings to the north of Bahira. No corresponding seam has been

proved in the areas to the east and west to suggest any precise correlation.

III. Upper Birsinghpur-Bindabanpur seam.

The upper thick seam of shale and coal cropping out at Khode (Khoodia) colliery, reported to be of a total thickness of 35 feet, probably continues eastwards as the seam, of approximately similar thickness, which is exposed at Bindabanpur colliery. To the west, this seam is doubtless represented by the upper coal seam of the Kanauri measures, whilst to the east of Bindabanpur it probably grades into the thick seam of shale and coal that crops out in the old working just north of Siulibari village. East of the Barakar river it cannot be recognised with certainty. The seam is, as a whole, of an inferior quality.

IV. Rangamati-Gopinathpur-Bahira '5'-Salanpur 'C'-Gourangdi-Churulia-Kastu seam.

West of the Barakar river.

Included within the massive grits and sandstones of the Nirsa-Mugma area, of the western end of the coalfield, is the Rangamati-Gopinathpur coal seam. These grit outcrops, within which the coal seam persists, can be followed almost continuously as far east as the Dudhapani area. The coal-horizons include one thick basal seam of coal and shale of some 20 feet in the west, with several thin seams intercalated within the strata immediately above. At Garphalbari, this main seam is about 15 feet in thickness and is followed by at least one 3- to 4-foot seam a short distance above. Within the faulted tract around Kumhardubhi, it is difficult to locate the equivalent of this coal seam with any degree of certainty. Tentatively, it is suggested that it may be represented by the seam that crops out in the flooded quarry workings just south of the Grand Trunk road, on the right bank of the Kol Jor, and which probably continues eastwards to the north of Chirkunda village, where it is represented at the surface by a well marked burnt outcrop.

East of the Barakar river.

East of the Barakar river, the equivalents of these seams are met with in the Ramnagar bore-holes (*see* Plate 16, bore-hole 3 & 4.) about 200 feet below the Laikdih seam; but on account of the oblique strike-fault, which runs between Ramnagar and Duburdih, the seams fail to crop-out at the surface. These coal seams, with their

associated massive sandstone strata, are undoubtedly represented in the Bahira (Borrea) area by Bahira '5' and '4' seams. Repeated by a strike-fault to the north, they crop out again in the Dendua area as Salanpur 'C' and 'D' seams. This correlation is proved conclusively by the bore-holes that have been put down between Bahira and Dendua villages (*see* Plate 16, sections 11 to 16). To the east of the Banbirdi area, it is doubtful whether the seams have been worked and in the absence of bore-hole records no details are available regarding their quality or thickness. From a lithological comparison of the lower Barakar sequence, however, the writer is convinced that within the Panuria-Jamgram area to the north-east, this coal horizon is represented by the main 20-foot Gourangdi-Kantapahari-Jamgram seam, and still further east, at Churulia, by the main Churulia seam. On similar reasoning, he regards this seam as equivalent to the Pariarpur-Kasta-Arang—Raswan seam of the Trans-Adjai field.

V. Shampur '5 and 6'-Chatabar-Patlabari-Laikdih-Lalbazar-Bahira '1 to 3' seams.

Excluding the relatively thin Kudia seam, of only local value, to the west of the Barakar river, the next important coal horizon is represented by the closely associated lower Shampur seams—Nos. 5 and 6. The writer is personally convinced that these two seams, including an upper 30- to 40-foot and a lower 9- to 10-foot seam of coal with shale and stone partings, are equivalent to the two similarly associated seams of the Chatabar basin. In several respects the seams closely resemble one another, and the geological structure and nature of the underlying Kudia shale and massive grit beds, substantiate this correlation. Within the Kudia syncline, these measures are absent, but where they recur in the Kalian Chak area, an equivalent coal seam, reported to be almost 45 feet in total thickness, is included, and is being worked at Patlabari colliery. The correlation of this coal seam with the thick Laikdih seam of the flooded quarries, to the south of Kumardubhi, is based on less direct evidence. This latter area is, unfortunately, badly faulted. No evidence has, however, been forthcoming to render this assumed correlation improbable. Assuming that the apparent thickness of the Laikdih quarry seam—said to be 80 to 90 feet—is not due to repetition by faulting, it entails a fairly rapid local thickening of the coal. That this seam belongs to the middle Barakar measures is agreed by all who have

recently examined the area, and in the absence of direct negative evidence alone, the writer would prefer to correlate it as above suggested rather than to suppose it to be an entirely new seam, sprung without warning into local prominence. To the east of the Barakar river, there are very sound grounds for regarding the thick seam of Ramnagar and Lalbazar, in combination with the Ramnagar seam above it, as equivalent to the above-noted Laikdih-Patlabari etc., seams of the more western areas. In one bore-hole. located near the Barakar river, 600 yards south of Ramnagar village, the section of these seams is as follows:—

	Ft.	in.
Ramnagar seam	14	0
Sandstones	27	6
Coaly shale	1	0
Sandstones	24	9
Coal with *jhama* and mica-peridotite	69	6

In the more easterly bore-holes, and in the colliery workings of Ramnagar and Lalbazar collieries, these intervening strata increase to about 100 feet. This indicates that the strata intervening between the Ramnagar and Laikdih seams, thin westwards towards the Barakar river; it would, therefore, not appear improbable to find that these two coal seams had run together still further west in the Kumhardubhi area.

As has been previously suggested by Mr. Walker, it is agreed that the Laikdih seam is represented in the Bahira (Borrea) area by Bahira (1 to 3) seams. This assumption is rendered unquestionable by the additional evidence of the bore-holes that have in recent years been put down through the lower measures to the north of Bahira. This implies a decided decrease both in the thickness and quality of the coal seams as compared with the Lalbazar-Ramnagar area. It appears probable that this deterioration of the upper Bahira seams and their accompanying decrease in thickness continues eastwards. On account of the paucity of clear exposures, and the absence of collieries and of bore-hole records, it is impossible to follow the seams between Bahira and Itapora. Regarding the Gourangdi-Kantapahari area to the north-east, however, it is tentatively suggested that the thick seam of coal and shale, which occurs about 200 feet above the Gourangdi seam, may represent this coal-bearing horizon. From the evidence of bore-hole records this upper seam appears to attain a total maximum thickness of 27 feet, but of what quality it is difficult to say.

To the west of Bahira, this coal seam constitutes one of the most productive horizons of the Barakar measures. Various sections of the seam produce a metallurgical coke of very good quality. In several of the areas concerned, a 'ball structure' is characteristic of certain of the horizons within the seam. The coal is largely bright, and relatively rich in vitrain.

VI. Shampur '3 and 4'-Kharbari seams.

About 230 feet above Shampur No. 5 seam, within the Shampur basin, two closely associated seams of coal and shale, of relatively inferior quality, are met with. These seams include a lower 14-foot seam and an upper 21-foot seam. It is suggested that the lower of these two seams is represented in the Chatabar area by the 15-foot Kharbari seam occurring about 170 feet above the main Chatabar seam of group V. The overlying measures are, apparently, absent in the Chatabar area, and also in the Kudia synclinal to the east. Further east, in the Chanch-Laikdih village area, and again east of the Barakar river, these coal seams appear to have died out, or are represented by the thick carbonaceous shales that occur within the 600 feet of unproductive measures above the Ramnagar seam.

VII. Top Fotka-Chanch-Begunia seam.

Within the uppermost coal measures of the Shampur area, the 10-foot 'Top Fotka' seam, of relatively good quality, is overlain by thick massive sandstones. These upper measures are absent eastwards until we reach the Chanch locality, where a seam of similar character, quality and thickness is met with. The equivalence of these two coal seams is further supported by a study of the lithological succession of the two areas. On similar grounds the Chanch seam, again represented at Dumarkanda colliery, is undoubtedly proved to continue east of the Barakar river as the 10-foot Begunia seam. 'Ball structure' and a considerable proportion of bright coal is again characteristic of this seam. To the east of Kendua, the Begunia seam decreases in thickness, being about five feet thick beneath the Ironstone Shales to the south of Bahira. Its correlation with the 4-foot seam of Rampur colliery to the south of Salanpur railway-station, is probable, whilst its equivalence with the uppermost seam, of similar thickness, within the Kantapahari-Jamgram area is possible.

About 200 feet above the Begunia seam of the Begunia village area, is a 3-foot seam, the topmost seam of the Barakar measures. A seam of approximately the same thickness is met with at about the same horizon above the Chanch seam, and also above the Top Fotka seam of the Shampur area.

CHAPTER XV.

DETAILED GEOLOGY AND CORRELATION OF THE COAL-BEARING DAMUDAS.—*contd.*

Raniganj Measures.

Distribution.

The outcrops of the Raniganj measures, including those areas hidden by laterite and alluvium in the eastern end of the coalfield, comprise a total of nearly 307 square miles, that is to say, almost half of the total area of the Gondwana strata of the coalfield, when reckoned as far east as longitude 87° 20′. The enormous extent of these outcrops is due in part to the relatively great thickness of the measures—of the order of 3,300 to 3,400 feet in the west—and also, largely to the fact that the beds are, in most cases, inclined at very gentle angles and occur, in some instances, as wide shallow synclinal troughs or low anticlinal domes. For some distance east of the Barakar river, the succession is tolerably well-exposed, but even in the majority of these sections the softer shales and coal seams are hidden, either as a result of the terminal creep of the overlying sandstones, or by a superficial soil-capping. East of Asansol, laterite, soil and alluvium prevail over wider tracts, though the harder sandstone horizons continue to crop out as low ridges as far east as Jambad; but in the extreme east, even these beds are largely hidden from view and are exposed only in the deeper stream sections, which have eroded through the lateritic capping. Fortunately, however, the information derived from a large number of colliery-workings, deep shaft-sections, and bore-holes, has given a very fair idea of the sequence of these beds within the greater part of the coalfield. Representative sections of the various horizons have been tabulated (*see* Plates 17 and 18) and these illustrate the lateral changes that take place within the measures.

In describing the Raniganj rocks of the coalfield, it is convenient to divide the area of outcrops into the following five tracts:—

I. Deilya (Deoli)-Nituria area. (South of the Damodar river).
II. Dishergarh-Asansol area.
III. Asansol-Sekpur-Raniganj area.
IV. Tapasi (Toposi)-Sonpur-Andal area.
V. Semalya (Samla)-Purushottampur-Jhanjra area.

TABLE 6.—*The Raniganj measures.*—(Classification into stages.)

STAGE.	DEILYA (DEOLI)-NITURIA AREA.	DISHERGARH-ASANSOL AREA.	ASANSOL-SEKPUR-RANIGANJ AREA.	TAPASI (TOPOSI)-SONPUR-ANDAL AREA.	SEMALYA (SAMLA)-PURUSHOTTAMPUR-JHANJRA AREA.
v	Hirakhun sandstones (300 ft.).	Bharat Chak-Kumarpur sandstones. (300 to 350 feet).	Uttardhadka-Satpukhuriya-sandstones Kotaldihi and shales with coal seams. (850 feet).	Andal-Dakshinkhanda sandstones and shales with thin coal seams (thinning to 600 feet in the east).	
iv	Nituria coal measures. (700 feet).	Chinakuri-Fatehpur-Bansarakdih coal measures. (650 to 700 feet).	Kalipahari-Siarsol coal measures. (250 to 350 feet).	Mangalpur-Kajora-Jambad-Sunkerpur coal measures. (250 to 300 feet).	Upper coal measure of the Jhanjra-Konardihi area.
iii	Hijuli sandstones with thin coal seams. (1.150 feet).	Seetalpur-Aldihi-Manoharbahal coal measures. (1,250 feet).	Majiara-Rana-Shripur—Satgram coal measures. (800 to 900 feet).	Toposi-Kenda-Chora-Sonpur coal measures. (1,200 feet in the west) (900 feet in the east).	KendraPurushottampur coal measures.
ii	Deoli coal measures. (400 feet).	Sitarampur coal measures. (400 to 450 feet).	Baraboni-Shibpur-Damodarpur—Sekpur coal measures. (500 feet).	Dhasala-Dahuka coal measures. (thinning to 175 feet in the east).	Samla sandstones and shales (about 150 feet).
i	Amdhaura sandstones. (700 feet).	Ethora sandstones. (650 to 700 feet).	Domahani-Taltor sandstones. (600 feet).	Hijalgara-Chichuria sandstones. (thinning to 376 feet in the east).	? absent.

During Lower Gondwana times, these various tracts doubtless formed one connected region of sedimentation. As a result of subsequent earth movements and of erosion, they have now been rendered structurally or topographically more or less distinct. The Raniganj rocks have been divided into five stages, which, in spite of considerable lateral changes in sedimentation, can be recognised with a fair degree of certainty throughout the coalfield (*see* Table 6). No interruption in sedimentation is, however, suggested by this sub-division. As in the case of the Barakar measures, local names have been applied to these stages within the separate areas, and these indicate the approximate locality across which the beds crop out at the surface or underlie the superficial capping of soil, laterite, or alluvium.

I.—Deilya (Deoli)-Nituria area.

To the south of the Damodar river, including the area south-west of Raniganj, the strata of the upper coal measures crop out over a total area of nearly 63½ squares miles. The area under consideration includes the colliery localities of Parbeliya, Saltor, Deilya (Deoli), Chaurashi (Chowrassi), Nadiha (Nodiha), and Puapur, exploiting the lowest seams of the Raniganj series, together with the small workings of Hirakund, Nituria and Murulia, where certain of the thin coals of the upper part of the measures have been extracted.

Collieries.

The lower Raniganj measures, swinging round steadily to the south-west in the vicinity of Saltor island, crop out near the junction of the Barakar and Damodar rivers, and, displaced by the Deoli cross-fault, continue in a south-35° westerly direction *via* Narayanpur and Nadiha, as far as Baghmara, where they are truncated by the boundary-fault that limits the Gondwana outcrops to the west of Panchet hill. The dips of these lower beds are in a general south-easterly direction, steepening, as the beds are followed south-westwards, from about 12° at Saltor, to 24°—30° in the Puapur-Baghmara area. Overlying these lower measures, the middle and upper Raniganj rocks crop out over wide areas to the south-east and east, the inclination of the beds decreasing in these directions.

Structure.

Within the Parbeliya-Bhamaria-Bonra area, the uppermost beds form a very shallow syncline pitching eastwards, in which direction they are overlain by the basal Panchets. Further south,

in the approach to the main boundary-fault, a series of alternating anticlines and synclines or synclinal basins (truncated by the boundary-fault) are observed. Within these truncated troughs, of Panchet and Gorangi hills, the Panchet and Supra—Panchet beds overlie the uppermost Raniganj measures. A well-marked fault, with a downthrow to the north-east—possibly the south-easterly continuation of the Deoli fault—intersects the higher measures near Saontal Motha, and, following along the axial line of the low anticline that divides the Nituria synclinal from the truncated Gorangi hill trough, it causes the upper-middle Raniganj beds to crop out in the area between Murulia and the junction of the Bisram and Machkanda streams. Still further east, between Gorangi and Biharinath hills, the upper Raniganj rocks continue in an elongated gentle dome, truncated to the south by the main boundary-fault, whilst to the north and east the topmost measures dip at low angles beneath the Panchets. In addition to the main Deoli fault, and its suggested continuation to the south-east, several minor displacements affect the lower measures of the Nadiha area. Small faults have been proved in the Parbeliya-Nituria tract, while further east, a number of cross-faults are observed, complicating the Raniganj-Panchet boundary.

Intrusions.

No dolerite intrusions are met with in this area, though a number of relatively small mica-peridotite dykes have been proved in the colliery workings, and others are observed at the surface intersecting the Raniganj beds. As a whole, however, the area appears to be relatively free of these ultra-basic intrusives.

The Raniganj measures of this area have been divided into the following stages :—

v. Hirakhun sandstones (300 feet).
iv. Nituria coal measures (700 feet).
iii. Hijuli sandstones, with thin coal seams (1,150 feet).
ii. Deoli coal measures (400 feet).
i. Amdhaura sandstones (700 feet).

The details of these various stages are as follows :—

i. Amdhaura sandstones.

Within this stage are included the basal Raniganj strata, predominantly of sandstone type. The sandstones include massive, grey and greenish-grey, fine to medium textured, felspathic varieties. with which are associated harder calcareous and sideritic bands

and subordinate grey shales. To the north-east of the Deoli fault, these beds doubtless underlie the alluvium and soil-capping in the vicinity of Bijra village, to the north of the Damodar river. South-west of the Deoli displacement, the beds crop out in the Amdhaura-Bambari area just south of the river, dipping S. 35° E. at angles of 15° to 19°. The passage down into the underlying Ironstone Shale beds is rapid though there is no evidence of any unconformity. To the south-west, the width of the outcrops narrows considerably, due at least in part to the steepening of the dips, though it is possible that a decrease in the thickness of the beds takes place in this direction and that local shearing may also have affected the measures.

ii. Deoli coal measures.

The strata of this stage include the principal coal seams of the area south of the Damodar, of which the Dishergarh seam is by far the most important. These measures comprise :—

(Shales with sandstones).
Dishergarh seam.
Sandstone and shales 200-220 feet (approx.).
Hatinal seam.
Sandstones and shales 125 feet.
Sanctoria seam.
(Sandstones).

North-east of the Deoli fault.

To the north-east of the Deoli fault, the Dishergarh seam is worked from inclines at Deoli colliery, from shafts to the dip at Saltor, and further east, at Parbeliya colliery. The seam is 15 to 16 feet in thickness and includes a band of ironstone inclusions, lenticular in cross-section. These ironstones in some instances exhibit a definite cellular structure, indicating that they are derived by the alteration of fossil wood. The coal is of an excellent quality including a large proportion of bright coal. These north-eastern Deoli and Saltor workings are limited to the south-west by the Deoli fault. The hade of this fault has been proved to be about 45° to the north-east, and what is possibly an offshoot of this main displacement has been met with in the south-western workings of the main Saltor mine. Further north, the Dishergarh seam evidently crops out beneath the river sand of the Damodar, just west of Saltor island, and is worked to the dip from shallow pits

located on the island. At Parbeliya colliery, the Dishergarh seam is worked from pits of a depth of 1,471 and 1,483 feet. The seam is of a thickness of 15 feet and is overlain by about four feet of dark shale within which are included well-preserved leaf-impressions of *Glossopteris* and *Schizoneura*. The dip is to the S. 16° E. at about 8°. The seam again includes a large proportion of bright coal whilst thin layers of silky 'fusain' are prominent. A somewhat indefinite narrow band runs within the seam about six to seven feet from its base, the lower section of the coal being at present worked; some ironstone inclusions are also encountered in the coal. The area appears to be relatively free from disturbances and igneous intrusions.

A boring is reported to have been put down in the vicinity of Nituria and to have proved the Dishergarh seam at about 2,000 feet.

No direct evidence is available regarding the Hatinal and Sanctoria seams of the above-described areas. It is more than probable, however, that they continue in depth, beneath the Dishergarh, and that important reserves of workable coal exist, at least within the lowermost seam.

South-west of Deoli fault.

On the south-western side of the Deoli cross-fault, the Dishergarh seam again crops out in the south-western incline workings of Deoli colliery. As in the case of the north-eastern incline workings, a very definite fault with a similar hade of 45° cuts off these south-western workings on the north-east side. But the area between the proved alignment of this fault, at the south-western outcrop of the seam, and the position along the same strike where the similar fault cuts off the workings of the north-eastern Deoli inclines, instead of being 500 feet (as one would expect were it one simple fault with a throw of 500 feet and a hade of 45°) is from 750 to 850 feet, therefore suggesting at least two parallel faults, or a zone of step-faulting from 250 to 350 feet in width.

The Dishergarh seam to the south-west of this faulted tract, is of somewhat inferior quality to that of the north-western workings. Further south-west, the seam decreases steadily in thickness to 12 feet at Nadiha, and nine feet as the Puapur workings are approached, and the quality also deteriorates. Bore-holes located a short distance to the dip, however, suggest that the seam is of greater thickness in depth, and an improvement in quality is probable. The marked hade of the Deoli fault should be borne in mind during future explorations to the south-east. Although the angle of 45°, which

exists in the Deoli workings, may be exceptional, any appreciable hade would considerably affect the line of intersection with the deeply-buried Dishergarh seam of these areas.

The Hatinal coal seam, some three to four feet in thickness, is possibly represented by the outcrop of shaly coal occurring in the south bank of the Damodar river, opposite the small island, north of Deilya village. It is apparently of very inferior quality.

The Sanctoria seam crops out a short distance below the Hatinal to the south-west of the Deoli fault. Like the above mentioned coal seams of the overlying measures, it appears to thin considerably and to deteriorate in quality to the south-west, and, although about six feet in thickness, the old inclines from which it was previously exploited are now completely closed. It is quite probable that, like the Dishergarh, these two coal seams improve in depth.

So far, no attempt has apparently been made to test these lower Raniganj measures to the north-east and east of Panchet hill. It is more than probable, however, that at least in so far as the Dishergarh seam is concerned, immense quantities of coal exist within a depth of 2,000 feet.

iii. Hijuli sandstones.

This thick sequence of sediments overlying the Dishergarh seam, includes a number of beds of massive sandstone alternating with shaly bands. Several thin seams of coal and shaly coal are included within the lower part of these measures and have been proved in the Parbeliya shaft-sections, and in the bore-holes to the dip of the Dishergarh seam outcrop to the south of Deilya and Nadiha.

iv. Nituria coal measures.

The lower portion of this sequence of alternating sandstone and shale strata is exemplified in the top of the Parbeliya shaft-sections, and includes several very thin seams of coal.

Hijuli coal seam.

Just above these horizons a 7-foot seam of inferior quality is met with. This seam—locally termed the Hijuli seam—crops out near the Parbeliya pits and the coal was apparently used during the sinking of the shafts. The seam probably represents the south-westerly continuation of the Bora Chak seam (*see* page 255). No section is available regarding the upper measures of this stage though, on the evidence of the equivalent succession to the north of the Damodar river, it is suggested that at least one coal seam —the equivalent of the Gopalpur seam—would be met with about 300 feet above this 7-foot 'Hijuli' coal seam. The upper part of

the measures of this stage doubtless crop out in the Machkanda Jor to the north of its junction with the Bisram stream, whilst to the south of the fault, which crosses the main *nala* about one mile north of Murulia, the lower strata of this stage, with the included thin seams of coal, are exposed. It is probable that the two above mentioned coal seams again crop out in the abandoned incline-workings to the east and west of Murulia and near Saontal Motha villages. Such a correlation suggests that the Dishergarh seam would probably be encountered, at a depth of not more than 1,500 feet, in the vicinity of the railway-bridge that crosses the Bisram stream half a mile north of Murulia. The measures of this stage include characteristic dark shales with ironstones, which can be recognised in several localities. At least the uppermost horizons of the stage again crop out within the elongated dome to the north of the main boundary-fault between Gorangi and Biharinath hills.

Dishergarh seam near Murulia.

v. Hirakhun sandstones.

These uppermost Raniganj measures include the predominantly massive sandstones of the Hirakhun-Bhamaria area to the east of Nituria. They also comprise a large part of the Raniganj outcrops of the Kashtagora-Tentularakh area between Gorangi and Biharinath hills, and are again exposed across the tract between Gorangi hill and the northern base of Panchet hill. Between Hirakhun and Nituria collieries, the 5-foot Hirakhun seam is included within the base of these measures, and has been worked from several inclines. In the above mentioned areas to the east and south this coal seam, which is apparently of relatively inferior quality, has not been definitely proved.

Hirakhun seam.

II.—Dishergarh-Asansol area.

This tract of upper coal measure strata, lying north of the Damodar river, comprises some of the most productive localities of the coalfield. Within it, the well-known Dishergarh seam attains its maximum thickness and certain of the higher coal seams are of considerable economic value. The structure is simple; the strata, striking east-north-eastwards across the Damodar into the Sanktorya-Bharat Chak area, continue

Structure.

steadily in this direction up to the Narsamuda-Ethora locality, beyond which the beds curve slightly to the south and continue, with an almost due east-west strike, to the longitude of Asansol. The inclination of the beds is normally 9° to 12° to the south-south-east or south. Unfortunately, however, the rocks have been subjected to considerable igneous injection. Of these intrusions,

Intrusions.

several dolerite dykes, including the Sitarampur and Narsamuda dykes of the middle portion of the area, and the thick Salma dyke of the extreme east, are well-observed. These, on account of their very direct trend and local habit do not hamper the progress of colliery development to any great extent. In addition, however, a number of dyke and sill-intrusions of ultra-basic type are met with, of which the latter—horizontal—variety being so variable in their mode of occurrence and having such a deleterious effect on the coal, have played havoc with several of the principal seams of the lower part of the measures.

The area includes the well-known colliery localities of Dishergarh, Sanktorya (Sanctoria), Shitalpur (Seetalpur) and Sodepur

Collieries.

in the west; Aldihi, Methani and the Dhemo group in the middle; Raghunathbati, Manoharbahal and Chinchuria in the east; and the smaller concerns of Bharat Chak, Patmohna, Bora Chak, Narsamuda and Bansarakdih to the south. To the south-west, the strata continue across the Damodar river undisturbed by large displacements, but to the east, cross-faults separate the area from the Barabani (Baraboni)-Satpukhuriya Kalipahari tract. Within this disturbed tract, north-east and east of Asansol, marked lateral changes take place in the coal seams, so that in addition to being structurally disconnected, these two areas—roughly east and west of the longitude of Asansol—are to some extent lithologically distinct.

The Raniganj measures of the Dishergarh-Asansol area have been divided into the following five stages, approximately equivalent to those already described to the south of the Damodar river :—

v. Bharat Chak-Kumarpur sandstones (300 to 350 feet).
iv. Chinakuri-Fatehpur-Bansarakdih coal measures (650 to 700 feet).
iii. Seetalpur-Aldihi-Manoharbahal coal measures (1,250 feet).
ii. Sitarampur coal measures (400 to 450 feet).
i. Ethora sandstones (650 to 700 feet).

The details of these various stages are as follows :—

i. Ethora sandstones.

This thick sequence of unproductive rocks, crops out over a wide tract of moorland and paddy-field country in the vicinity of the villages of Hatinal, Gangutia, Kultara, Ethora and Bijari. The beds comprise a sequence of massive, fine-textured, relatively soft, felspathic sandstones of grey and greenish-grey tints, sometimes speckled with grains of decomposed red felspar. Included within these softer sandstone strata are a number of hard, calcareous, sideritic bands, whilst shaly sandstones and grey shales occur at intervals. The succession is very well exposed in the railway-cutting west of Sitarampur station. Within these basal measures, one 5-foot seam of coal and shaly coal is, apparently, included. This Gangutiya seam is described in Mr. Walker's account of the coalfield,[1] as occurring about 100 feet below the Sanctoria seam (of the base of stage ii). No exposures, nor any workings into this seam could, however, be seen and it is evident that he obtained his information from the records of bore-holes located within the western part of this tract, and that the seam is, probably, of too inferior a quality to be of economic worth.

Gangutiya seam.

ii. Sitarampur coal measures.

The measures of this stage include three coal seams, two of which —the Sanctoria and Dishergarh seams are of considerable economic importance. The following two sections, representative of the Dishergarh-Seetalpur area in the west, and the Chinchuria locality in the extreme east, exemplify the changes that take place laterally within the area under discussion :—

Dishergarh-Seetalpur area.		*Chinchuria area.*
(Alternating sandstones and shales)		(Alternating sandstones and shales)
Coal 16 to 19 ft. . . .	(Dishergarh seam)	*Coal* 8 ft.
(Sandstones and shales, varying from 240 to 300 ft. thick) .		(Sandstones and shales about 210 ft. thick).
Coal with shale bands, varying up to 9 ft.	(Hatinal seam) .	*Coal* with shale bands, 6 ft.
(Sandstones and shales with massive sandstones below, about 140 ft. thick).		(Sandstones and shales, about 170 ft. thick).
Coal with shale band, 10 ft. .	(Sanctoria seam) .	*Coal* 12 ft. 6 in.

[1] *Trans. Min. Geol. Inst. Ind.*, VII, p. 245, (1913).

Sanctoria seam.

The Sanctoria seam is apparently the one referred to by Dr. Blanford[1], the section of which is given by him as follows :—

(Carbonaceous shale.)	Ft.	in.
Coal	1	2
Shale	1	0
Coal	0	9
Shale	0	2
Coal	6	0

The coal is of good quality and has been worked to a large extent to the west of the Purulia road, but within certain areas around Dishergarh and Seetalpur and to the east of the present Seetalpur workings, it is, unfortunately, considerably damaged by mica-peridotite intrusions. Further east, as far as Sitarampur, we have no authentic recent information regarding this coal seam. The outcrops are poor and no complete sections are exposed. Speaking in 1914, Mr. F. J. Agabeg[2], in referring to the area between Chhota Dhemo and the Salma dyke, remarked, however :—

'There is little doubt that the Sanctoria seam is burnt right along this outcrop. I am informed that to the south-west of Neamutpore (Niamatpur) village the Sanctoria seam has been bored to a depth of 1,500 feet and found to be totally burnt.'*

He further states that borings near the outcrop of the Sanctoria, near Bhandra (Bhannra), to a depth of 169 feet, proved the 'burnt' coal, and a deeper 520-foot boring to the south gave similar results. He continues :—

'To satisfy myself I sank a trial-shaft; in this shaft the seam was 6 feet 6 inches thick and totally burnt.'

In this connection, within the Dharmma *nala* section, just east of Kalikapur, a 4-foot mica-peridotite dyke intrusion is observed intruded into grey shale at approximately the horizon of the Sanctoria seam, whilst further east, to the west-south-west of Kanyapur village, outcrops of mica-peridotite sills are noted within the lower measures of this stage, and in the vicinity of Nuni and Chinchuria villages, borings have proved the seam to be largely converted to *jhama* and unworkable. There is little doubt that the 12 ft. 6 in.

[1] *Mem. Geol. Surv. Ind.*, III, p. 113, (1861).
[2] *Trans. Min. Geol. Inst. Ind.*, IX, p. 30, (1914).
* The writer suggests that, in this connection, the term 'burnt' doubtless implies that the coal has been coked as a result of mica-peridotite intrusions

coal seam of Chinchuria colliery represents the easterly continuation of the Sanctoria. The coal of the Sanctoria seam is of a bright streaky nature and includes occasional hard, ferruginous, coarse-textured nodules, similar to those met with in the Poniati seam to the east. East of Chinchuria, in the old workings of Napara colliery, the seam is reported to have thickened to about 16 to 18 feet, a thickness corresponding to that of its equivalent coal seam—the Poniati—of the Jayramdanga area, from which it is separated by the two cross-faults that limit these latter workings to the west.

Hatinal seam.

The Hatinal seam is of inferior quality, though it has been worked in the past, and during the more recent boom, within the Sanktorya area. It is not exploited at Chinchuria colliery, but an old incline, located a short distance south of Chinchuria village, is situated on the strike of the outcrop of the seam. To the east of Chinchuria, the seam apparently thickens to nine feet, and has been worked in the past in the southern inclines of Napara colliery.

Dishergarh seam.

The Dishergarh seam, doubtless of greatest individual importance within the coalfield, can be followed almost continuously from the north side of the Damodar river, east-north-eastwards to Sitarampur, east of which it can be observed at intervals in abandoned incline-workings within the Sudi-Kanyapur tract. Around and to the west of Sitarampur, the outcrop of the seam is marked by large flooded quarries and inclines, bearing evidence of the wasteful methods of coal-extraction during the earliest days of mining within the field. The seam is now worked almost wholly from shafts located to the dip, and varying in depth up to over 1,100 feet. Ranging from 16 to 18 feet in the west, though in some instances reported to attain as much as 20 feet in total thickness, the seam thins to about 12 feet near Sitarampur, and to 8 feet at Kanyapur and Chinchuria. A short distance east of Chinchuria colliery it decreases rapidly in thickness, and is proved by a bore-hole located near the Nonia Khal to be only 3 feet 6 inches thick. A short distance east of this bore-hole, the strata are displaced by the south-westerly continuation of the faults that limit the area to the east. East of the Dharmma *nala*, within the Sudi-Marichkata tract, the seam is intersected by mica-peridotite intrusions, and for apparently the same reason has not been successfully worked between Marichkata village and Kanyapur colliery. To the dip, it retains a thickness of about 16 to 18 feet in the west, though it

thins to about 11 to 12 feet within the 'Dhemo' area; it has been proved to be of a thickness of 12 feet 6 inches in the 1,950-foot bore-hole at Narsamuda, and 10 feet at Bansarakdih. To the rise of Narsamuda, however, within the vicinity of Ganrui, the seam has, apparently, been largely destroyed as a result of mica-peridotite intrusion. In this connection, Mr. Agabeg[1] observes that a bore-hole, located near Raghunathbati, proved the seam to include a 3-foot upper section of *jhama* and a lower 9-foot section of clean coal, whilst a deeper bore-hole to the south, penetrating the seam at 480 feet, proved that the whole of the seam was destroyed. He notes also, that similar results were obtained from a 1,000-foot bore-hole located at Gandui (Ganrui) the whole thickness of the seam being converted into *jhama*. The following sections denote the changes that take place in the seam within the more western areas :—

Seetalpur (No. 3 Pit).	Ft.	in.	*Seetalpur* (Bore-hole No. 5).	Ft.	in.	*Chhota Dhemua.*	Ft.	in.
Coal . .	17	0	*Coal* . . .	15	6	*Coal* . .	16	6
Shale . .	1	0	Shaly fireclay .	4	0	Shale . .	0	6
Stone . .	1	6	*Coal* . . .	1	6	*Coal* . .	2	6
Coal . .	3	0						

Bejdihi.	Ft.	in.	*Dhemo Main.*	Ft.	in.
Coal . .	15	0	*Coal* . . .	11 to 12	0

The roof of the seam is usually composed of shales or shaly sandstones, but the floor rock appears to vary in type. In quality the seam is excellent, though it deteriorates somewhat in the eastern part of the area.

iii. Seetalpur-Aldihi-Manoharbahal coal measures.

Bara Dhemo and Raghunathbati seams.

When followed north-eastwards, across the Damodar river, the thin coal seams of the Hijuli sandstone stage of the south thicken appreciably, and to the east at Sitarampur they are represented by the closely-associated Bara Dhemo and Raghunathbati seams, and by the Lower Dhadka seam. These lateral changes are well illustrated in the deep shaft and bore-hole sections of Seetalpur, Methani, Dhemo Main and Narsamuda (*see* Plate 17). A number of other thin seams of coal and shale, apparently of no present economic

[1] *Trans. Min. Geol. Inst. Ind.*, Vol. IX, p. 31, (1914).

value, have also been proved. The Bara Dhemo and Raghunathbati seams occur about 450 to 500 feet above the Dishergarh seam. Shaly representatives of these coal seams first come into prominence in the Bejdihi-Methani area, the included coal being of an inferior quality. The sections of these shaly seams are as follows:—

Bejdihi shaft-section.	Ft.	in.	*Methani shaft-section.*	Ft.	in.
Coal	5	6	*Coal*	3	0
Band	1	0	Strata	8	0
Coal	1	0	*Coal*	8	6
Band	0	4			
Coal	5	8			

Inclines located near Aldihi village proved the seams to be represented by bands of poor quality coal including intercalations of shale and shaly sandstone, of a total thickness of 14 feet. At Lachhipur colliery, these strata occur as two separate coal seams, a lower 10-foot and an upper 4-foot seam, separated by a sandstone band only 1½ feet in thickness. East of this colliery, these two seams continue with greater individuality, and the bed of sandstone that separates them increases to about 80 feet.

The following sections illustrate this transition:—

Chhota Dhemo colliery (near the Grand Trunk road).	Ft.	in.		*Raghunathbati-Sarakdih area.*	Ft.	in.
Coal . . .	4	0	(Raghunathbati seam).	*Coal* . .	4	6
Strata . . .	51	6		Strata . .	70 to 80	0
Coal with shale band	11	0	(Bara Dhemo seam)	*Coal* with shale bands . .	8 to 9	0

Within this Chhota Dhemo-Sarakdih area, the Bara Dhemo seam is of an inferior grade, though it has been worked in the past from a number of inclines. The Raghunathbati seam is, however, of very good quality and is still being extracted at the above-mentioned collieries. In the deep Narsamuda bore-hole, these two seams retain their individuality and thickness. To the east of Sarakdih, the seams have apparently been exploited in the past at Panchgechhia colliery, in the eastern inclines of which the section included a 6-foot upper seam separated from a lower 3-foot seam by 20 inches of strata. That a rapid lateral variation takes place within these coal seams in the vicinity of Panchgechhia is undoubtedly the case, for at Manoharbahal, a short distance to the east, a single coal seam of a thickness of eight feet is included at an horizon

equivalent to that of the Raghunathbati and Bara Dhemo seams of Sarakdih. This 8-foot Manoharbahal-Bara Pukhuriya seam includes a lower 6- to 7-foot section of good quality coal. In one bore-hole to the dip, the seam appears to split up into several thin separate sections, but in others it retains its thickness and individuality. Within this eastern area, the strata intervening between the Dishergarh and Manoharbahal seams thicken, in some instances, to nearly 600 feet.

Manoharbahal seam.

About 130 feet above the Raghunathbati seam of the Sarakdih area, is a 3-foot coal seam, which has, in the past, been worked from inclines near Nadiha village. In the upper part of the stage, about 400 feet above the Raghunathbati seam, a seam of shaly coal, represented in the west by several thin coaly bands, is prominent in the eastern half of the area. Represented by a 3-foot seam within the Dishergarh shafts of Dhemo Main colliery, this seam thickens to the east to about 9 to 10 feet. This thickness, however, includes a number of shale bands, and the coal being of relatively inferior quality, all the old incline-workings located along its outcrop to the east are now abandoned. The seam is locally termed the Lower Dhadka seam.

Seam near Nadiha.

Lower Dhadka seam.

iv. Chinakuri-Fatehpur-Bansarakdih coal measures.

Overlying the above-described measures is a series of alternating sandstone and shale strata including a number of seams of shale and coal, among which only two—the Bora Chak and the Gopalpur seams—have proved of economic value. These two coal seams are fairly regular within the Dishergarh-Asansol area. The Bora Chak seam, occurring about 1,350 to 1,400 feet above the Dishergarh seam, crops out in the south-west in the vicinity of Chinakuri, and it was apparently this coal seam that was worked in the old Chinakuri mine by Mr. Betts, in the years 1826-1830. The section given by Mr. Williams is as follows[1] :—

Bora Chak seam.

	Ft.	in.
Coal, inferior	6	0
Carbonaceous shale	0	4
Coal, inferior	1	2
TOTAL	7	6

[1] A Geological Report on the Damoodah valley by D. H. Williams, Esq., printed 1850.

Further east, in the bore-holes at Patmohna, the seam has been proved to be 10 feet in total thickness. Several abandoned inclines occur on its outcrop between Bara Dhemo village and the Nonia stream, and the seam was being worked at the time of the present survey from shallow pits at Fatehpur colliery. The Bora Chak seam is here 10 feet in total thickness, an 8-foot section being extracted. It is again being exploited near Bansarakdih, to the north of Asansol, where it is nine feet thick including several thin bands of shale and shaly coal. About 210 to 235 feet above the Bora Chak is the Gopalpur seam. In most instances, this seam appears to be of a thickness of about 4 feet 9 inches. It has been proved by bore-holes and inclines within the Patmohna area, and further north-east in the vicinity of the Nonia stream, and to the north of Asansol, abandoned incline-workings mark the outcrop at intervals. The coal of both these seams appears, however, to be of a relatively inferior grade.

Gopalpur seam.

v. Bharat Chak-Kumarpur sandstones.

These uppermost Raniganj measures include the fossil-wood (Dadoxylon) sandstones of the Kumarpur railway-cutting. Within the sandstones of this stage is included a seam of shale and shaly coal, several feet in thickness. This seam crops out in the Nonia Jor at the right-angle bend north-east of Kumarpur village. A short distance below, at the base of the stage, is the Narsamuda seam—the topmost coal seam of economic importance within the Raniganj measures. This coal seam is represented just north of the Damodar river by the Bharat Chak seam which, under the title of the 'Salunchi seam', was worked in the distant past at Chinakuri or Salunchi colliery to the west of Bharat Chak village. The section of the seam, as given by Dr. Blanford[1], is as follows:—

Bharat Chak-Narsamuda seam.

(Massive sandstones).	Ft.	in.
(Shale	9	0)
Coal	7	0
Shale	0	4
Coal	3	6
TOTAL	10	10

[1] *Mem. Geol. Surv. Ind.*, III, p. 116, (1861).

Only the 7-foot section was worked, and was reported by him to be of good quality.

At Bharat Chak and Patmohna, the seam is 10 feet thick, of which the middle 4 feet 6 inches is of good quality. Again to the north-east, at Narsamuda colliery, the seam has been worked in the past for a number of years, where it includes a total of only 4 feet 6 inches of fair quality coal. Further east, the outcrop doubtless continues near the village of Shitala to the north of Asansol.

III.—Asansol-Sekpur-Raniganj area.

As has been previously mentioned, a marked lateral variation takes place within a number of the coal seams of the Raniganj series about the longitude of Asansol, and again within the Sekpur—Raniganj tract. The strata within which these changes occur are also affected by several cross-faults, which add, in some instances, to the difficulty of arriving at a detailed correlation. Within the very extensive area between these two relatively narrow transition zones, the measures also exhibit lateral changes, but of a more gradual type, and although traversed by a number of faults of very considerable displacement, it is possible to follow the equivalent coal-horizons with a fair degree of certainty.

Structure.

The western half of the area under discussion is traversed by the large Mohishila (Muslia)-Banbishnupur cross-fault with a downthrow of about 240 feet in the latter locality, though further north between Charanpur and Banksimila, this relative displacement is partly compensated by the strike-fault that limits the former area to the south.

Question of fault between Shripur and West Jamuria.

The question of the continuation of the strike-faults of the southern Charanpur area to the south-east, is of considerable importance. Within the stream-section to the south-west of Banksimila colliery the strata to the south-east of the Banbishnupur-Charanpur cross-fault are definitely disturbed. The bore-holes *immediately* south of Banksimila colliery point to the absence of any large dislocation, but, since the rocks are largely hidden by soil, we have no evidence to substantiate this undisturbed state of the measures still further south. If we continue the trend of these Charanpur strike-faults to the south-east *via* Pariharpur village, they intersect the area between the present workings of West Jamuria (near Baijantipur village) and Shripur collieries. Again,

however, there is no definite evidence, though the following facts are of interest. At West Jamuria colliery, the Poniati seam is met with at a depth of about 520 feet, the general dip being to the south-west at the gentle grade of 1 in 15 (3° 49′). That the seam continues to dip fairly steadily in this direction, for a distance of at least 200 yards to the south-west of the pits, is proved by a bore-hole (Jamuria No. 5 D. B.) that reached the Poniati seam at a depth of 550 feet. Now, at Shripur colliery, still further south-west, the Poniati seam is again met with at a depth of about 943 feet. In the southern workings of this colliery, the seam dips to the south-west at about 1 in 13, but in the northern workings it appears to roll over slightly towards the north-east, though the workings do not extend for any great distance in this direction. In order to accommodate these facts, therefore, either :—

(*i*) the inclination of the strata, intervening between Jamuria bore-hole No. 5, and the northern workings of Shripur colliery, must increase rapidly to an average grade of at least 1 in 9 (6° 20′) ; or

(*ii*) a fault, with a downthrow to the south-west must traverse this unproved tract.

Near the north-eastern end of the railway-cutting, which traverses a portion of this area, a zone of mica-peridotite dyke intrusion causes the local shattering of the exposed sandstone strata. A fault might well accompany this zone of disturbance. Should such a displacement occur within the area, the evidence of the bore-holes to the south-east suggest that it dies out within the tract west of Banali.

To the north-north-east of Asansol, the beds strike in a general east-west direction, but as the Mohishila-Banbishnupur displacement is approached they swing round to the south-east, and in the case of the upper measures, to a north-south strike in the vicinity of the fault. In the areas adjoining this displacement considerable lateral variation takes place within the coal seams of the upper part of the measures, so that within the vicinity of Kalipahari to the east, the detailed succession shows marked differences from that of the Satpukhuriya area to the north-west. Again, in the eastern part of the area, the Jamuria-Raniganj cross-fault, with a downthrow to the west of the order of 150 feet, intersects the measures, and is succeeded further east by several parallel displacements proved, up to the present time, only within the lower part of the measures. East of the Mohishila-Banbishnupur fault, the strata follow a general east-south-easterly and south-easterly trend, but as the

Jamuria-Raniganj displacement is approached, the beds swing round to the east and north-east. In general, the dips of the strata are southerly. In the Jayramdanga-Barabani area and to the south, the inclination of the lower beds is about 10°, though much steeper grades are recorded to the north of the strike-fault, just north of Barabani village, whilst the higher measures to the south, dip at rather more gentle angles. Further east, the inclination of the lower coal-bearing stages varies from 5° to 6°, though to the south of Damodarpur and Sekpur, several low rolls appear to affect the measures. The higher beds are again gently inclined to the south-west and south, but between the Grand Trunk road and the Damodar river, in the south-eastern part of the area, they form a broad synclinal pitching eastwards towards, and truncated by, the Jamuria-Raniganj cross-fault.

Siarsol-Raniganj synclinal.

To the south of the Damodar river, the upper Raniganj strata dip at gentle angles beneath the Panchets to the south-west and south, though the uppermost horizons are again exposed as small inliers within elongated domes in the approach to the main southern boundary-fault. To the south of Damulia, the strata, included within the southern limb of the Siarsol-Raniganj synclinal, swing south-west across the Damodar, and appear to turn southwards towards the boundary-fault. In the vicinity of Jemua, rocks of the Raniganj series again crop out against the boundary-fault.

Intrusions.

In the west and south, dolerite intrusions are represented by the south-easterly continuation of the Saima dyke, together with the parallel intrusion, which comes in to the south of the Damodar river. Smaller branch intrusions of a similar type also intersect the Satpukhuriya-Charanpur, and Kotaldihi areas. Ultra-basic intrusives, occurring both as dykes and sills, abound in certain tracts and, in addition to hampering the present colliery workings, have considerably damaged certain of the coal seams over wide areas. They are, however, less prevalent within the upper horizons of the measures.

Collieries.

The area is one of very considerable mining activity, including the Jayramdanga, Baraboni, Charanpur, Shibpur and Damodarpur groups of collieries in the north, followed to the dip by the deeper shafts of Jamuria, Shripur and Ningah, all working the Poniati seam of the lower portion of the measures. The upper seams are exploited from the

mines of Kalipahari, Ghoshik (Ghusick), and Kumardiha in the south-west, and of Siarsol and Raniganj in the south-eastern portion of the area.

Stages.

The strata have been divided into the following five stages. As a result of the lateral changes that have taken place within the measures to the north of Asansol, in order to reconcile this division with the natural grouping of the coal seams, the upper stages have been slightly re-arranged as compared with the classification west of Asansol (*see* also Table 6). These five stages include :—

v. Uttardhadka-Satpukhuriya-Kotaldihi sandstones and shales with coal seams (850 feet).
iv. Kalipahari-Siarsol coal measures (250 to 350 feet).
iii. Majiara-Rana-Shripur-Satgram coal measures (800 to 900 feet).
ii. Baraboni-Shibpur-Damodarpur-Sekpur coal measures (500 feet).
i. Domahani-Taltor sandstones (600 feet).

The details of these various stages are as follows :—

i. Domahani-Taltor sandstones.

Taltor seam.

These basal sandstones, with intercalated shaly sandstones and shales crop out over a wide tract, varying up to two miles in width, to the north of the colliery-districts of Baraboni, Charanpur and Shibpur. Within the upper part of this stage, a 4-foot coal seam—the Taltor seam—has been proved to the north of Charanpur. Again further east, it crops out to the north-west of Nandi village and has been worked to a small extent from inclines and shallow pits. The seam is here 4 feet 6 inches thick and of inferior quality, but to the east, near Sekpur, it apparently increases to six feet and its quality also improves. It is suggested that this seam is represented by the 6-foot basal seam of the Palasdanga bore-hole to the south of Damodarpur (*see* Plate 17, bore-hole 28).

ii. Baraboni-Shibpur-Damodarpur-Sekpur coal measures.

These measures include the important Poniati-Sibpur seam, the equivalent of the Sanctoria of the west. Followed above by the Koiti—the easterly continuation of the Hatinal seam—these two oal seams reach their maximum development within the western

and middle portions of the area, but in the extreme east, and to the dip, they thin considerably and deteriorate in quality. The Poniati seam is, however, more persistent than the overlying Koiti seam. About the horizon of the Dishergarh seam of the west, a relatively thin coal seam is proved in a number of bore-hole and shaft sections. The seam is, however, of inferior quality and has never been worked. The strata intervening between the Koiti and Poniati seams in the vicinity of their outcrops varies from about 120 feet in the west, to 150 feet in the east, whilst to the dip, a slightly greater thickness of beds is included.

Poniati seam.

The Poniati seam, 18 feet in thickness, is worked from a number of inclines and shallow pits in the Jayramdanga area and continues within the 90-foot *horst*-faults that limit the Barabani locality. The seam includes some characteristic coarse-textured 'boulders' of ironstone, lenticular in cross-section. Certain of these inclusions exhibit a marked cellular structure. They occur within a fairly definite 9-inch band, about 12 feet from the base of the seam within the Baraboni workings. To the north of these areas the Poniati seam, together with the Koiti, is locally repeated by a large oblique strike-fault, and has been worked, largely in the past, from quarries north of Barabani. To the dip, the seam has been proved to be of a thickness of 16 feet to the west of Majiara, but within the bore-hole located about 550 yards south-east of that village it was found to be converted into *jhama*. To what distance this zone of igneous intrusion extends, it is, without the evidence of further bore-holes, impossible to say. Throughout the Charanpur workings, the seam retains its character and thickness and is again 17 feet thick in the shafts of Banksimila. To the dip at Shripur colliery it is 15 feet 9 inches in thickness, including a similar band of shale with ironstone varying from 1 inch to 7½ inches thick, and occurring about 11 feet from the floor; whilst further south at Ningah colliery from 14 feet 6 inches to 15 feet are recorded, including a 9-inch band of shale about eight feet from the floor of the seam. Within the coal, inclusions of ironstone are again met with. East of Shibpur, the seam thins perceptibly both to the east and to the dip, so that in the western workings of Damodarpur colliery it is 13 feet thick and only 9 to 10 feet in the eastern workings, whilst at Sekpur a thickness of less than nine feet is recorded. A short distance to the dip of these collieries, an appreciable decrease in thickness takes place, so that in the Akholpur and Mandalpur

workings the Poniati varies from about 9 to 10 feet (including a 9 to 15-inch stone band in the middle) in the rise workings to about four feet within the dip workings, a similar decrease in thickness being observed in the Banali and Palasdanga bore-holes to the south. In regard to the deep bore-hole at Bagra (Bogra) (*see* Plate 17, bore-hole 22) it is unfortunate that this section was not continued to a greater depth within the lower Raniganj measures. Although at first sight the evidence suggests that the Poniati seam has thinned beyond recognition, and is represented by one of the thin coal-seams of the base of the bore-hole, if, on the other hand, one supposes that the unproductive strata, intervening between the Poriarpur-Satgram and the Poniati seams, had increased slightly in thickness in this area, then it is evident that the latter seam may not have been reached in the bore-hole; it might, in fact, underlie the strata of the base of the section by only a few feet.

Across the western and middle portions of the area the seam is of excellent quality, but in the extreme east it is of a slightly inferior grade. In the Jamuria, Charanpur, Shibpur and Shripur collieries in particular, large mica-peridotite dykes and local sill-intrusions intersect the coal seam.

Koiti seam.

The Koiti seam retains a thickness of about 12 feet in the northern colliery-workings as far east as Banksimila, but like the Poniati, it decreases in thickness and deteriorates in quality further east, and is not worked in the eastern part of the area. To the dip it retains its thickness in the Banksimila shafts, and is about nine feet thick in the vicinity of Jamuria; at Shripur colliery it is represented by alternating bands of shale and inferior coal of a total thickness of 18 feet, whilst in the deeper bore-holes of Ningah and Banali, it is considerably thinner and is regarded as of no present economic worth.

iii. Majiara-Rana-Shripur-Satgram coal measures.

These middle Raniganj measures comprise a thick sequence of sandstone and shale strata within which a number of coal seams are included. Though inferior in quality to the better class coals of the underlying stage, these seams are nevertheless of considerable economic importance, and have been worked extensively within certain parts of the tract under consideration. The strata are well illustrated in the Majiara bore-holes of the west, and in the

Ningah and Bagra sections further east. Briefly, the succession includes :—

West of the Kalipahari-Banbishnupur fault.	*East of the Kalipahari-Banbishnupur fault.*
(*Lower Dhadka seam*—of stage iv.)	(*Nega seam*—of stage iv.)
Sandstones and shales 170 ft. (approx.)	Sandstones and shales, including the 3½-foot Century seam in the east—300 to 400 ft.
Seam of *coal* and shale 6 ft. 6 in.	*Shripur seam.*
Sandstone and shales 100 to 130 ft.	Sandstones and shales, variable; usually 100 to 150 ft.
Rana seam.	*Poriarpur-Satgram seam.*
Sandstones and shales including several thin seams of shale and coal, attaining a maximum thickness of 10 ft. in the Rana locality—500 ft. (approx.).	Sandstones and shales, including several thin seams of coal and shale—400 to 500 ft.

Rana-Poriarpur seam. The Rana seam, the equivalent of the Poriarpur-Satgram seam of the east, and of the Manoharbahal seam of the west, is of a thickness of eight feet (including two thin shale bands) and the quality is moderately good. West of Rana colliery the seam is not worked, though it is proved within the Majiara bore-holes to be of a thickness of from 5 to 5½ feet. To the east of the Kalipahari-Banbishnupur fault, the seam again crops out to the west of Pariharpur (Poriarpur) village, and continues south-eastwards *via* Shripur colliery to Banali and Satgram. Between Pariharpur and Shripur it is 9 to 9½ feet thick, but increases in the Banali area to 12 to 13 feet and to a total of about 15 feet at

Banali-Satgram seam. Satgram, where the following section was recorded :—

	Ft.	in.
Shaly *coal*	2	0
Shale	0	11
Good *coal*	6	2
Shale	0	8
Inferior *coal*	4	0
Shale	0	2
Inferior *coal*	1	2
TOTAL	15	1

To the dip, the seam is now being extracted in the recently constructed 250-foot shafts, a quarter of a mile north-east of Kankhaya village. Here the seam is of good quality and is significant in including a band of bright nodular coal, one of the few instances of this

'ball structure' within the seams of the Raniganj measures. The section of the seam is as follows:—

	Ft.	in.
Coal	9	0
Shale	1	6
Coal	1	6

Further south, within certain of the Ningah bore-holes, the seam was found to have split up into a number of relatively thin seams of unworkable character, though to the south of Banali the thickness, as noted at the outcrop, appears to continue to the dip at least to a depth of 350 feet, the top six to eight feet being reported to be of good quality.

We have no exact evidence of these measures immediately to the east of the Jamuria-Raniganj fault. It is, however, suggested that the equivalent of the Satgram seam would be met with at no great depth in the vicinity of Katagaria village.

Bolompore colliery.

It is possibly the continuation of the Poriarpur-Satgram coal seam that crops out again within the southern limb of the Siarsol-Raniganj synclinal, in the north bank of the Damodar river at Bolompore colliery, near Raghunath Chak village. A number of old workings exist near the outcrop, and two recently constructed shafts had been sunk to the north and were reported to have proved the seam, at a depth of about 200 feet, to include a total thickness of about 13 feet, though in the old workings to the south the section was given as follows:—

	Ft.	in.
Shale	0	6
Coal	6	9
Shale	1	0
Sandstone	6	6
Coal	5	6

The dip is northerly, at a very gentle angle.

Shripur seam.

The Shripur seam is known as such only within the vicinity of Shripur village, where it crops out. The seam is of inferior quality and about seven to eight feet thick, though in the Ningah bore-holes to the south it includes a somewhat variable thickness of coal and shale. It is probably represented to the west by the 6½-foot seam of the Majiara bore-holes, and in the Banali-Satgram area to the east by the 7 to 9-foot seam of inferior quality. In the vicinity of and to the west of Shripur village, the seam appears to be the seat of a thick sill-intrusion of

mica-peridotite, and similar intrusions are observed on the surface at the suggested outcrop of this coal seam, between Rana and Majiara. As a result, the coal was found to have been converted into *jhama* in one of the Ningah bore-holes, in the shafts north of Kankhaya, and in the eastern bore-hole of the Majiara area.

iv. Kalipahari-Siarsol coal measures.

Majiara area. Within the 300 feet of strata above stage (iii), to the west of Majiara, three seams of coal and shaly coal are included as follows, in descending order :—

	Ft.	in.
Coal	8 to 9	6*
Sandstones and shales	30 to 40	0
Coal and shale	3 to 4	6
Sandstones and shales with thin seams of shaly coal .	200	0(approx.)
Coal	6 ft. 6 in. to 7	0†

Again, in the upper part of the bore-hole, located about half a mile west of Kankhaya village, a short distance west of the Kalipahari-Banbishnupur fault (Plate 17, bore-hole 20) equivalent horizons were passed through, including a number of thin coal seams, varying up to 6 feet 6 inches in thickness. But to the dip, a deep boring located a short distance east of Asansol, and several other bore-holes between the Grand Trunk road and Mohishila (Muslia) village, all west of the Kalipahari-Banbishnupur fault, proved the same horizons to include near the top of the stage, a seam comparable to that of the Ghusick. Immediately east of the Kalipahari-Banbishnupur fault, in the vicinity of the Grand Trunk road, the succession is as follows :—

Kalipahari area.

	Ft.	
Coal	10 to 12	(Ghusick seam).
Sandstone varying up to .	10	
Coal and shale . . .	9	(Ghusick 'A' seam).
Sandstones and shales with two thin bands of *coal* . .	100 to 120	
Coal	8	(Kushadanga seam).
Sandstone and shales . .	60 to 75	
Strata including three *coal* and shale seams varying from 5 to 8½ ft. in individual thickness .	100	(These coa seams=Nega seam of the south-east).

* (The lowest seam of the pits of Kalla colliery and probably the equivalent of the Bora Chak seam of the west.)

† Probably the equivalent of the Lower Dhadka seam of the west.)

The succession of coal seams as represented in this south-eastern area is, therefore, very different from that of the Majiara outcrops to the west of the Kalipahari-Banbishnupur fault. It should be borne in mind, however, that at the time of the deposition of these measures—previous to their displacement by faulting—the strata cropping out in the Kalipahari area were continuous with those met with in depth just north-west of these outcrops, on the west side of the fault, and that the measures of the Majiara outcrops were deposited at a distance of over a mile to the north of the latter. The principal variation, therefore, appears to take place from the outcrop to the dip in the area west of the fault, and a similar change is noted in the Satpukhuriya measures of the overlying stage.

Variation to the dip.

Lateral variation also takes place within the Kalipahari-Siarsol measures further south-east (*see* Plate 17) as indicated by the following representative sections :—

Ratibati-Kumardiha area.	Ft.		*Jemeri-Siarsol area.*	Ft.	
Coal . . .	11 to 12	(Ghusick seam)	*Coal* with thin shale bands .	19	(Siarsol seam).
Sandstones and shales, a few feet, variable					
Shaly *coal* and shale .	8 to 9				
Sandstones and shales	120		Sandstones with some shales, about .	200	
Coal, inferior . .	8	(Kushadanga seam)			
Sandstones and shales	110				
Coal with thin bands of shale . .	18	(Nega seam)	*Coal* with thin shale bands .	22	(Nega-Raniganj seam).

The Ghusick seam is the most important coal seam of the Kalipahari-Kumardiha tract, and is being worked at a number of collieries. The closely associated lower seam —Ghusick 'A'—which underlies it, includes inferior coal and shale and is not extracted. Several well marked cross-faults complicate the strata of this area. The Ghusick seams are overlain by a thick series of dark grey shales, and underlain by

Ghusick seam.

massive, green-grey sandstones. No information could be obtained regarding their continuation east of the Nonia Khal, though from a comparison of the lithological sequence, it is suggested that the seam is thrown southwards by a dip-fault, which appears to run south-south-westwards between Chalbalpur and Jemeri collieries, and would be met with beneath the alluvium a short distance south of the Nonia stream to the north of Tirat.

Siarsol seam.

The Siarsol seam crops out as an irregular arc to the west of Siarsol and Raniganj villages, within the truncated synclinal of the south-eastern part of the area. Like the Ghusick seam, it is overlain by dark-grey and sandy shales and the upper half of the seam is of better quality. The section as given at Siarsol colliery (Messrs. Gillanders Arbuthnot & Co.), is as follows:—

		Ft.	in.
Good *coal*	10 to	11	0
Band		0	2
Coal		0	10
Shale		0	2
Coal		4	9
Band		0	5
Coal, inferior		2	6
TOTAL		19	10

The seam continues in thickness to Raniganj colliery, where it is again worked.

Kushadanga seam.

The Kushadanga seam is apparently of workable quality and thickness—7 to 8 feet—in the northern part of the Kalipahari area, where it is extracted at several small collieries. The seam is of relatively poor quality and thins eastwards. It is possibly represented among the seams of carbonaceous shale and shaly coal exposed in the Nonia stream to the south of Chalbalpur, and further east near Murgathaul village.

Nega-Raniganj seam.

The Nega seam is variable in character in the vicinity of Kalipahari, but from Ratibati eastwards it retains its individuality and thickness, cropping out *via* Jemeri and Nimcha villages. Just east of the Kalipahari-Banbishnupur fault, it comprises several relatively thin seams at present

of unworkable value. These seams are represented at Kalipahari and Muslia collieries by the following sections:—

Kalipahari colliery. (Pits Nos. 1 & 2.)

	Ft.	in.
Coal	4	9
Shale	0	3
Coal	0	9
Shale	0	3
Coal	0	6
(Sandstone . . .	50	0)
Coal	2	0
Shale	1	0
Coal	0	5
Shale	0	1
Coal	2	8
TOTAL .	12	8

Muslia colliery. (Pit No. 3.)

	Ft.	in
Coal	5	0
Shale	0	3
Coal	0	9
Shaly sandstone . .	0	5
Coal	0	5
Shale	0	1
Coal	3	4
Shaly sandstone . .	0	2
Coal	0	6
Shale	0	1
Coal	3	0
TOTAL .	14	0

Further south-east at Ratibati and Jemeri collieries, the seam includes the following sections:—

Ratibati colliery. (Pit No. 2.)

	Ft.	in.
Coal	7	10
Band	0	2
Coal	0	10
Band	0	2
Coal	4	2
Band	0	½
Coal	0	6
Band	0	½
Coal	2	10
TOTAL .	16	7

Jemeri colliery. (After Blanford.)

	Ft.	in.
(Shale)		
Shaly *coal*	1	0
Shale	0	1
Inferior *coal* . .	2	0
Coal	8	0
Shale	0	2
Coal	0	8
Shale	0	1
Coal	4	3
Shale	0	1
Coal	0	6
Shale	0	1
Coal	4	0
TOTAL .	20	11

Within the Siarsol-Raniganj syncline, the seam is worked at Siarsol colliery (Messrs. Gillanders Arbuthnot & Co.), and at Raniganj colliery (Messrs. Burn & Co.). In the former colliery, about 200 feet of strata appear to separate the seam—here known as the Raniganj seam—from the overlying Siarsol seam, though in the Raniganj pits these intervening beds appear to have thinned to

about 150 feet in thickness. The section at Siarsol colliery is as follows :—

	Ft.	in.
(Grey shale)		
Shaly *coal*	7	6
Shale	0	3
Coal, good	8	0
Band	0	1
Coal	0	7
Band	0	1
Coal, good	4	6
Band	0	4
Coal shaly	4	6
TOTAL	25	10

The topmost section of shale and coal appears to have increased in thickness in this locality, though in other respects the seam closely resembles that of Jemeri and Raniganj.

In agreement with Dr. Blanford, the writer is convinced that it is the same Nega-Raniganj seam that has been worked in the past in the vicinity of Egara. The old incline and quarry workings of this area denote the outcrop of the seam on the south side of the Siarsol-Raniganj syncline. A fault, which cuts off the old quarry-workings to the west of Egara, and which apparently dies out to the north-east, throws the outcrop of this seam southwards to the vicinity of Damalia, where it crops out beneath the pebbly alluvium of that area, and was extracted in the early days of coal-mining within the Raniganj field. As is noted in the following sections taken from Dr. Blandford, the seam has apparently thinned to the south, towards these outcrops.

Raniganj colliery.

	Ft.	in.
(Shale)		
Coal	9	0
Shale	0	3
Coal	0	9
Shale	0	2
Coal	3	0
(Shale)		
TOTAL	13	2

Damulia (Damalia) colliery.

	Ft.	in.
(Shale)		
Coal	6	0
Ironstone	0	1
Coal	3	0
Shale	0	1
Coal	0	9
Shale	0	3
Coal	6	0
TOTAL	16	2

Such evidence suggests that the seam would be met with beneath the massive sandstones that crop out to the north-west

of Egara between the Nonia stream and the East Indian railway, at depths varying from about 80 feet in the south, to 150 feet in the north. The middle-upper section of this Nega-Raniganj seam is of very good quality.

About 75 to 80 feet below the Raniganj seam in the southern (Egara) limb of the syncline, is an 8 to 9-foot seam of inferior quality —the Narrainkuri seam—worked in the past at Narrainkuri colliery. This coal seam is possibly represented in the northern limb of the synclinal by the 3½-foot seam of Century colliery.

Narrainkuri seam.

It is tentatively suggested that the Raniganj and Narrainkuri coal seams swing south-westwards across the Damodar river to the south of Damalia, and crop out again in the Kalikapur area, within the workings of Kalikapur and Banskunri collieries. The strata intervening between these two seams of Kalikapur mainly include massive sandstones similar to the succession observed in the Egara area. The seams comprise :—

South of the Damodar river.

	Ft.	in.
Coal seam	10	6
(Strata about 75 ft.)		
Coal seam	6	6

The evidence of the Raniganj seam, thinning to the south towards its outcrop within the Egara-Damalia area, further suggests this correlation.

To the south of Raniganj, the three coal seams appear to swing round almost parallel to the south easterly continuation of the Raniganj fault, and crop out in the workings of Napur colliery, where they dip steeply to the east-north-east and are cut off by the fault a short distance to the dip. The succession here includes :—

Napur colliery.

	Ft.	
(Thick shales)		
Coal seam	22	(Siarsol seam).
(Mainly sandstones)		
Coal seam about	15	(Raniganj seam).
(Sandstones about 90)		
Coal seam	6	(Narrainkuri seam).

To the east of this main fault, and apparently limited a short distance further east by a second displacement, a 15- to 16-foot coal seam crops out in an arc, dipping south-eastwards in the inclines of Raniganj colliery. On account of the faulted nature of the area, it is at present impossible to suggest the exact equivalence of this coal seam.

The upper, Ghusick, seam of this stage appears to have been proved in the bore-holes at Bakulia and Majit, to the south of the Damodar. In these sections the seam is about 10 feet in thickness, including a 5- to 8-inch shale band in the middle. At Gopalnagar, (near Salchur) further south-east, several shale bands are included within the seam. This evidence suggests that the coal seams of these upper Raniganj measures deteriorate in quality and in thickness in the area south of the Damodar river.

Ghusick seam south of the Damodar.

v. Uttardhadka-Satpukhuriya-Kotaldihi sandstones and shales with coal seams.

These measures include the whole of stage (v.) *plus* the upper half of stage (iv.) of the Dishergarh-Asansol area. West of the Kalipahari-Banbishnupur fault, within the Uttardhadka-Satpukhuriya area, the succession closely resembles that of the west; but east of the fault, as a result of lateral variations within the sediments, in order to conform to the natural grouping of the coal seams a somewhat lower horizon has been chosen as the dividing line between these two stages. The following sections indicate these lateral changes within the sediments:—

(A) WEST OF KALIPAHARI-BANBISHNUPUR FAULT.

Uttardhadka-Satpukhuriya area (near outcrop).	Ft.	In.		*Eastern end of Asansol* (to the dip).	Ft.	In.
			(Panchet sandstones and shales).			
			Uppermost Raniganj massive sandstones with shales 200 to 300 feet.			
Coal . . . 3½ to	4	0		*Coal*	4	6
Sandstones and shales .	80	0		Sandstones and shales .	86	0
Shaly *coal* and shale .	3	6		Shaly *coal* . . .	4	0
Sandstones and shales with thin bands of *coal*	260	0		Sandstones and shales with thin bands of *coal*	276	0
Coal	9	0	(Upper Dhadka-Satpukhuriya seam).	Inferior *coal* with shale bands . . .	8	0
Strata	200	0		Strata . . .	200	0
Coal = Bora Chak seam 8 to	9	0		*Coal* = Ghusick seam .	10	0

(B) EAST OF KALIPAHARI-BANBISHNUPUR FAULT.

Bore-hole just west of the Salma dyke (¼ mile east of Mohishila village). (Upper strata not represented).	Ft.	In.		*Radhamadhupur bore-hole.* (Upper strata not represented).	Ft.	In.
Strata	83	0		Sandstones and shales, including two thin coal seams . . .	168	0
Shaly *coal* . . .	7	6	(Satpukhuriya seam) .	*Coal* seam, inferior .	8	0
Strata	171	6		Massive sandstones with shales at base . .	166	6
Coal	7	0	(Ghusick seam) . .	*Coal*	12	0

From these sections it is observed that, as in the case of the Bora Chak-Ghusick seam, very considerable lateral variation takes place within the Upper Dhadka-Satpukhuriya coal seam when followed to the dip in the area to the west of the Kalipahari-Banbish-

Lateral variation in coal seams.

nupur fault. In this case, however, the change is one of diminution in thickness and deterioration in quality, so that to the east of Asansol, and within the Damra-Kumardiha area to the south-east of the fault, the seam is only seven to eight feet in thickness and of very inferior quality. Within this latter area, it has been proved in an old incline to the north-west of Kumardiha village.

Upper Dhadka-Satpukhuriya seam.

Within the Uttardhadka-Satpukhuriya area, the Upper Dhadka-Satpukhuriya seam, the easterly continuation of the Gopalpur seam of the west, is of quite good quality, and is now worked at Kalla, Satpukhuriya and Banbishnupur (Bonbistopur) collieries. The details of this seam are as follows:—

Dhadka colliery.	Ft.	in.	*Satpukhuriya colliery.*	Ft.	in.	*Banbishnupur colliery.*	Ft.	in
Coal .	4	0	*Coal* including shale band varying from 6 inches to 2 feet in thickness . .	9	6	*Coal* .	4	0
Band .	2	6				Band .	1	3
Coal .	4	0				*Coal* .	3	9

The 3½- to 4-foot upper seam, occurring about 350 feet above the Satpukhuriya seam, has been worked from inclines within the faulted tract of Kalla colliery to the south-west of Satpukhuriya, and again further south in the vicinity of the Grand Trunk road. To the south-east of the Banbishnupur fault the seam has not been developed though it is probably represented by the outcrop of shale and coal in the north bank of the Damodar river, a short distance west of the Salma dyke. This uppermost seam probably represents the easterly continuation of the Narsamuda seam of the west.

South of the Damodar river.

To the south of the Damodar river, the measures of this stage have apparently been proved in bore-holes located near Bakulis and Majit villages, where the succession includes:—

	Ft.	
Several thin seams of *coal* and shaly *coal* up to 1 foot in individual thickness.		
Sandstones	43	(approx.).
Coal and shale	5	
Massive sandstones with shales and several thin coaly bands .	200	(approx.).
Coal and shale	7½ to 8	(?=Satpukhuria seam).
Sandstones with shales at the base	170 to 180	
(*Coal* with shale band . .	9 to 10	(?=Ghusick seam of stage iv.).

IV.—Tapasi (Toposi)-Sonpur-Andal area.

Lateral variations in the measures.

The marked thinning of the Poniati and Koiti coal seams of the lower Raniganj measures, within the Damodarpur-Sekpur area, has already been described. This decrease in thickness apparently continues eastwards within the Tapasi-Sonpur area, but, in addition, lateral changes are observed in various other horizons of the lower and middle Raniganj measures. These changes include:—

(*a*) The gradual thinning of the basal Raniganj sandstone and shale strata to 376 feet at Chichuria.

(*b*) The incoming of an important coal seam at about the same horizon as the Dishergarh seam of the western end of the field. This seam first comes into prominence as the 'Chowkidanga seam' of the Tapasi area, and thickens eastwards to about 17 to 18 feet as the Dobrana seam.

(*c*) The thickening of the Satgram seam to form the 30-foot Toposi-Kenda seam of the eastern area.

(*d*) The marked decrease in the thickness of the strata intervening between the Chowkidanga-Dobrana and Toposi-Kenda coal seams, as compared with the thickness represented in the middle portion of the coalfield.

Regularity of upper seams.

In contrast to these marked lateral changes, the two main seams of the upper Raniganj measures—the Raniganj and Siarsol seams—continue in thickness and quality at least as far as Kajora, and much further east in the case of the upper, Siarsol-Upper Kajora, seam. In the eastern Kajora area, however, the lower of these two seams, the Raniganj-Lower Kajora seam, appears to combine with a 9-foot seam, the Bansra-Sonachora seam, below it, to form the thick 40-foot Jambad-Bowlah seam of the eastern end of the coalfield. As a result of these transitions, the division into stages has been conveniently re-arranged to conform with the natural grouping of the coal seams.

The area includes certain of the oldest colliery workings of Tapasi, Dhasala (Dhasul), Mangalpur and Babuisol, together with the more recent mines of Kajora, Jambad and Shankarpur (Sunkerpur).

Within the eastern half of this area, the Raniganj strata are almost completely hidden beneath laterite and alluvium. Fortunately, however, from the evidence of the colliery-workings and bore-hole sections, one is able to obtain a very fair idea of the stratigraphical succession (*see* Plate 18) and structure in the case of the greater portion of the area, though further information will be required before the complete elucidation of the southern Raniganj-Baktarnagar-Andal area; the north-western Mahmudpur area; and the

north-eastern Sonpur-Dalurband tract, is possible. In general, the inclination of the strata is to the south-south-east or south-east at gentle angles. The area is traversed by a number of dip- and strike-faults of very considerable throw. In some cases direct evidence is available, the fault having been proved within the colliery workings; in others, only its approximate position can be indicated. Three main dip-faults traverse the area; these include:—

Dip-faults.

(*a*) The *Singaran* fault, which follows a south-south-easterly direction and separates the Toposi-Singaran colliery areas from those of Joto Janaki and Kenda. Further north-west, this fault probably links up with the large 'Badul' fault of Mr. Walker's survey, and displaces the Raniganj-Ironstone Shale boundary to the extent of nearly three quarters of a mile to the west of Barul village. To the south of Tapasi, we have no direct evidence of this displacement until we reach the Sonachora area. In this latter area, it divides the old Mangalpur workings from those of Sonachora colliery. Within the Tapasi area, this fault throws down to the west about 300 feet.

(*b*) The *Dobrana-Siduli* dip-fault, which follows a general south-30° east to south-easterly trend, separates the workings of the Kenda and Jambad areas from those of Chora and Bahula. It throws down to the south-west to the extent of about 60 feet in the north increasing to perhaps 90 feet in the south. South-eastwards it affects the workings of Siduli colliery.

(*c*) The *Hansdiha-Shankarpur* (*Sunkerpur*) dip-fault can be noted only approximately, for although its position is fairly well defined in the Shankarpur area, it is indicated to the north-west only on the evidence of a few bore-holes and more distant colliery-workings. It appears to throw down to the south-west to the extent of about 120 to 150 feet.

Strike-faults.

Two main zones of strike-faulting have been proved and include:—

(*a*) The *Kajora-Siduli-Bankola* fault, which follows a general north-easterly trend and apparently cuts across the above-described dip-faults with little or no change of direction or character. Within the Kajora area, this disturbance appears to include two approximately parallel trough-faults. To the south-west of Mukundarpur village, these comprise a south-easterly fault of about 160 feet downthrow to the north-west, and a north-westerly parallel displacement which throws down in the opposite direction to the extent of about 50 feet. These faults separate the workings of the Parashkol area from those of Khas Kajora colliery. To the south-west, these two displacements intersect the upper measures of the Kajora tract. To the north-east, at least one of these faults continues *via* the Siduli pits to Bankola, where a resultant downthrow of about 100 to 120 feet to the north-west is proved at Bankola colliery.

(*b*) The *Shankarpur* (*Sunkerpur*)-*Sitalpur* strike-fault runs almost parallel to the Siduli-Bankola fault, about 1,150 yards north-west of the latter. To the north-east, its position is indicated with a fair degree of certainty by a number of bore-holes, which have been put down to the north of Sunkerpur colliery, whilst west of Sitalpur village a fault of similar type, with approximately the same downthrow of 130 feet to the north-north-west, has been proved to the north of the pits of

A. K. Patel colliery. Further south-west bore-holes point to the existence of a similar displacement running to the north-west of Parashkol village, but no additional evidence is available for fixing its exact position.

A number of smaller faults, up to a maximum of 63 feet throw, are met with in the workings of Babuisol collieries, and bore-holes to the east suggest the occurrence of other displacements, though it is impossible without further exploration to define their exact positions.

Igneous intrusions.

Comparing these colliery localities with the areas of Raniganj rocks to the west, the number of igneous intrusions that affect the measures is comparatively small. It must be borne in mind, however, that the exposures of the Gondwanas are here very limited and also that large tracts are at present undeveloped. No dolerite dykes are known to exist. Of mica-peridotite intrusions, several sills are met with in the vicinity of Siarsol to the south-west, and one large dyke, over 100 feet thick, is exposed half a mile south of Parasia. From the evidence of its direction within this area, this dyke would be expected to run north-westwards between Tapasi and Kunustara villages, though there is no evidence of its occurrence on the surface. It continues south-east to the north-western colliery of the Kajora group, but beyond this point there is evidence to suggest that it dies out rapidly and is not met with in the eastern collieries of Kajora. In other areas, several smaller dykes are observed on the surface and have been proved underground in the progress of colliery development.

For the purpose of description, the Raniganj strata have been divided into the following five stages:—

v. Andal-Dakshinkhanda sandstones and shales with thin coal seams (thinning to 600 feet in the east).
iv. Mangalpur-Kajora-Jambad-Sunkerpur coal measures (250 to 300 feet).
iii. Toposi-Kenda-Chora-Sonpur coal measures (1,200 feet in the west; 900 feet in the east).
ii. Dhasala-Dahuka coal measures (thinning to 175 feet in the east).
i. Hijalgara-Chichuria sandstones (thinning to 376 feet in the east).

The details of these various stages are as follows:—

i. Hijalgara-Chichuria sandstones.

Diminution in thickness to the east.

The basal sandstones, with shaly sandstones and shales, equivalent to those underlying the Taltor seam to the west, underlie the laterite and alluvium of the Hijalgara-Bahadurpur-Chichuria village areas. The evidence of a bore-hole to the south of the

latter village indicates that these basal unproductive measures have diminished in thickness to 376 feet in that locality, and additional evidence, noted below, suggests that this diminution continues in a still greater degree further north-east.

ii. Dhasala-Dahuka coal measures.

These measures probably include the equivalent of the Taltor and Koiti coal seam horizons of the west. Within the Mahmudpur-Mohanpur locality, to the west of the Singaran fault, several relatively thin seams have been proved by bore-holes. Three of these coal seams appear to be fairly constant (*see* Plate No. 18) and range in thickness up to about eight feet. They doubtless belong to the lowermost productive measures of the Raniganj series. A $4\frac{1}{2}$- to 5-foot seam has been worked a short distance to the south, just west of Sarthakpur village, where the strata dip S. 69° E. at a low angle. At East Nandi colliery to the east of the village, a 5- to 6-foot seam was being extracted, the dip being to the south at a gentle angle. But a short distance further east in the Singaran *n-l-*, much steeper inclinations varying up to 25° are recorded, and near Mohanpur to the north, easterly dips are observed. The area definitely appears to be much disturbed and without further information it is impossible to dogmatise on the exact correlation of these individual coal seams.

Mahmudpur locality.

East of the Singaran fault, the structure is less complex and within the area of Dhasala (Dhasul), the 8-foot Dhasul seam is included within the top of this stage. This coal seam, worked in the past near Dhasala village, is proved to the dip within the Tapasi and Jote Janaki areas to be of a total thickness of 11 to $13\frac{1}{2}$ feet, and $11\frac{1}{2}$ feet respectively, and to be separated from the Chowkidanga seam (the basal seam of stage iii.) by about 300 feet of relatively unproductive measures. Further to the dip, within the Babuisol area, a deep bore-hole proved an 8-foot seam at approximately the same horizon within the lower measures.

Dhasul seam.

To the east of Dhasala, these basal seams are unproved until we reach the Chichuria-Dahuka area. Within this tract, however, definite evidence of the succession is available. In addition to several bore-holes, which prove the coal seams of this stage only, we have the evidence of the deeper bore-hole, which penetrated below the lower seam of the stage and which, after passing through 376 feet of

Chichuria-Dahuka area.

unproductive measures, (stage i.) penetrated the uppermost beds of the Ironstone Shales. The succession as represented within this Chichuria-Dahuka area is, therefore, as follows :—

		Ft.	in.	
I.	*Coal*	8	6	(Chichuria seam).
	Strata	96	0	
II.	*Coal*	5	9	(Dahuka seam).
	Strata	46	0	
III.	*Coal*	1	6 to 2 ft.	

Several shafts have been sunk to the upper seam of this group and in some cases the middle seam was also extracted. The workings did not, however, extend very far before the collieries—Nibaun Chandra & Sarkar colliery and Gaudanga colliery—were closed down. The upper seam was apparently found to be of relatively inferior quality, though the middle seam, about four feet in thickness in the workings, included fair quality coal.

Conclusions arrived at by Walker.

Mr. Walker came to the conclusion that these three seams, I, II and III, represented the Koiti, Poniati and Taltor seams respectively. With this conclusion the writer is in general agreement; on the other hand it should be emphasised that the seams have changed so considerably with reference to their more important representatives of the west, that to press this correlation in detail so far as the individual coal seams are concerned, would be laying oneself open to the charge of forcing geological reasoning for the purpose of the coal-exploiter, in order that the seams may be worked and sold under names that have become popular to the purchaser who, in many cases, has little or no knowledge of the geological conditions of the area.

The writer's conclusions.

In conclusion, it may be observed that the available evidence points to the general thinning of the lowest Raniganj measures in this eastern part of the Raniganj coal-field; that the three closely associated coal seams of the Chichuria area occur at horizons approximate to those of the Taltor, Koiti and Poniati seams of the middle portion of the field, and that they may well be their equivalents. But, bearing in mind the lateral variation in these lower measures within the Sekpur-Mamudpur area, the disturbed nature

of the ground, and the absence of a continuous series of detailed sections, it would be unreasonable to state with any degree of certainty that the three lowest coal seams of the Asansol-Sekpur area and the three seams of the Chichuria locality are individually equivalent.

For some distance east of Chichuria no information is available regarding these lowest strata of the Raniganj series, though from the evidence of the faulted Samla-Kenda-Govindpur area to the north-east, it is suggested that the basal Raniganj measures continue to thin eastwards, and that the coal seams of stage (ii.) gradually die out in that direction.

iii. Toposi-Kenda-Chora-Sonpur coal measures.

Within the lower half of this sandstone and shale succession, two main coal seams are included—the Chowkidanga-Jote Janaki-Dobrana seam below, and the Toposi-Kenda-Chora-Sonpur seam above. Higher up in the stage, a seam of relatively inferior quality, the 8-foot Bonbahal seam of Singaran colliery, is represented, together with several thin seams, at least one of which thickens to about 12 feet in the eastern part of the area. The Chowkidanga-Dobrana seam, of relatively inferior quality, first springs into prominence at Toposi colliery where it includes:—

Chowkidanga seam.

	Ft.	in.
Coal	6	6
Band	2	0
Coal	4	0

It thickens rapidly eastwards and is reported to be 18 feet thick within the Jote Janaki area. Further east, near Dobrana village and at Bamesgoma colliery, its thickness is 16 feet, beyond which area it does not appear to have been worked, and no information is available regarding its thickness or quality at Sonpur. It is probably represented in the deep bore-hole at Babuisol by a 10-foot seam, and by an 11- to 15½-foot seam in the Parasia bore-holes. The Toposi-Sonpur seam, which, it is suggested is the thickened extension of the Satgram seam of the middle portion of the coalfield, occurs about 150 feet above the Chowkidanga-Dobrana seam. At Toposi colliery it is of the order of 28 to 30 feet in total thickness and continues about 30 feet

Toposi-Chora seam.

thick within the collieries of the Kenda area. Typical sections of this seam are as follows :—

Singaran colliery.

	Ft.	in.
Coal (inferior)	7	0
Shaly *coal* and shale	0	9
Coal with 3 to 4 thin shaly bands	20	0
TOTAL	27	9

Kenda colliery.

	Ft.	in.
Coal	6	6
Shale	0	4
Coal	8	0
Band	0	4
Coal	1	2
Band	0	4
Coal	2	7
Band	0	6
Coal	3	3
Band	0	6
Coal	4	0
TOTAL	27	6

Further east, the seam thins to about 25 to 26 feet at Harispur and Chora, to 22½ feet at Hansdiha, though at Sonpur (now closed) it is said to attain a total thickness of 26 feet. At Chora colliery, the section was given as follows :—

	Ft.	in.	
Shaly *coal*	5	0	
Band	0	6	
Coal	4	0	
Band	0	2	(A lower 21- to 22-foot section was worked at this colliery.)
Coal	3	0	
Band	0	2	
Coal	1	0	
Band	1	0	
Coal	13	6	
Total	28	4	

The Chora seam appears to continue in thickness to the dip and to be represented at Babuisol, at a depth of about 809 feet, by a 28-foot seam, and at Parasia by a 27- to 30-foot seam.

At Singaran colliery, an 8-foot seam of inferior quality has been worked from inclines. It occurs about 200 feet above the Toposi-Kenda seam. Again in the Chhora-Banbahal area, about 195 feet above the Chora seam, a 9-foot seam has been worked. This is possibly the easterly continuation of the upper seam of Singaran colliery and is reported to be 14 feet in total thickness at Banbahal. It is of relatively inferior quality.

Bonbahal seam.

iv. Mangalpur-Kajora-Jambad-Sunkerpur coal measures.

In the western part of the area these measures, including the thick Kajora-Jambad-Bowlah coal seams, are separated from the Toposi-Kenda-Chora seam by nearly 600 feet of relatively unproductive strata. To the east, however, these intervening strata appear to thin to about 500 feet. In the western Kajora-Babuisol locality, the measures of this stage include:—

Kajora-Babuisol area.

	Ft.	
Coal with thin shale bands . .	18 to 20	(Upper Kajora seam).
Sandstones with some shaly sandstones and shales	120 to 150	
Coal with thin shale bands . .	21 to 22	(Lower Kajora seam).
Sandstones	80 to 110	
Coal	9 to 12	(Sonachora-Bansra seam).

Within the eastern Kajora workings, and to the north and east between Parasia and Sunkerpur (Shankarpur), a marked change is noted in the running together of the two lower seams to form the thick Jambad-Bowlah coal seam, so that within these areas the succession includes:—

Jambad-Bowlah seam.

	Ft.	
Coal with thin shale bands . . .	18 to 20	(Upper Kajora-Khandra seam).
Massive sandstones with occasional thin bands of shale	190 to 220	
Coal with shale and shaly sandstone bands	40 to 45	(Jambad-Bowlah seam).

This correlation is substantiated by a bore-hole in the faulted tract of Siduli colliery. Within this bore-hole (Plate 18, bore-hole 43) the recognisable upper shaly measures (with thin coal seams) of the overlying stage (v) were first encountered, then a seam of coal with shale bands of a total thickness of 20 feet, representing the Upper Kajora seam. Below this seam was the typical sandstone succession similar to that which underlies the Upper Kajora seam of the Kajora area, of a thickness of 197 feet. These sandstones were followed below by a coal seam of a total thickness of 32 feet (including a 5-foot band of shaly sandstone), undoubtedly the equivalent of the Jambad seam.

Section of Siduli.

The similarity between the succession of the Babuisol-West Kajora tract, and the Raniganj-Siarsol area is so striking, both as regards the lithological sequence and the thickness, nature and quality of the coal seams, that in conjunction with the evidence afforded by the overlying and underlying strata, the writer is con-

vinced of the correctness of the following correlation of the coal seams of these different areas :—

3. Siarsol=Upper Kajora=Khandra seam.
2. Raniganj=Lower Kajora=Mangalpur seam.
1. Narrainkuri=Bansra=Sonachora seam.

The details of these coal seams within this eastern portion of the field are as follows :—

Bansra-Sonachora seam.

The Bansra-Sonachora seam crops out to the west of the Singaran fault along the laterite-capped ridge on which Banshra village is situated. The seam, nine feet in thickness, and of inferior quality, is worked from inclines to the north-east of the village. West of Banshra, it appears to swing westwards across the low ground to the south of Amrasota. East of the Singaran fault, the seam is extracted at Sonachora colliery, where it is again nine feet thick, the lower six feet being of better quality. Further east, in the Kajora area, this coal seam has been proved in bore-holes to be of a total thickness of 12 feet, whilst near Babuisol to the dip, it appears to range from 10 to 14 feet thick. At this latter locality the seam, 12 feet in thickness, has been worked by the Economic Coal Co.

Lower Kajora-Mangalpur seam.

The Lower Kajora-Mangalpur seam has been exploited in the past in the abandoned quarries of the Mangalpur ridge (*see* Plate 4) and is now being worked at Babuisol colliery and at a number of the pits of the Kajora-Parashkol area. The correlation of these seams with the Raniganj-Jemeri coal seam further west was formerly suggested by Dr. Blanford, and has been borne out during the present survey. Within the Mangalpur workings, to the west of the Singaran fault, the seam is reported by Dr. Blanford to include[1] :—

	Ft.	in.
(Sandstone).		
Inferior *coal* and shale	9	0
Coal	8	0
Shale	0	½
Coal	0	6
Shale	0	½
Coal	3	6
Shale	0	3
Coal	0	6
Shale	0	1
Coal	2	6
Total	24	5

[1] *Mem. Geol. Surv. Ind.*, III, p. 86, (1861).

Within the Kajora-Harishpur area the sections of the seams are as follows :—

Madhabpur and Harishpur collieries.
(after Blanford).

	Ft.	in.
(Sandstone).		
Shale and coaly shale	8	6
Coal	8	0
Shale	0	1
Coal	0	6½
Shale	0	1
Coal	4	2
Sandstone	0	8½
Coal	0	4
Shale	0	2
Coal	3	0
Total	25	7

Guzdar's Kajora colliery.

	Ft.	in.
Coal inferior . . . 7 to	8	0
Shale	0	3
Coal	7	6
Shale	0	1
Coal	0	6
Shale	0	1
Coal	4	3
Total	20	8
	(approx).	

Dutt's Kajora colliery.

	Ft.	in.
(Sandstone).		
Shale	1	0
Bad *coal*	7	0
Shale	2	0
Coal	6	9
Shale	0	9
Coal	4	9
Shale	0	9
Coal	2	0
Total	25	0

Palchoudury's Kajora colliery.

	Ft.	in.
(Sandstone).		
Shale	2	0
Coal	2	0
Stone	2	0
Coal	5	6
Stone	0	6
Coal	8	4
Stone	0	1
Coal	0	6
Stone	0	1
Coal	4	6
Total	25	6

Jadabhall's Kajora colliery.

	Ft.	in.
(Sandstone).		
Coal	8	9
Shale	0	6
Coal	7	8
Shale	0	7
Shaly *coal*	0	1
Coal	4	3
Total	21	10

A large fault, throwing down to the north-east, probably divides the Kajora from the Babuisol area. In the collieries of the latter tract, the Lower Kajora seam is again met with at depths varying from 100 to 140 feet. The section of the seam is reported as follows:

Babuisol area.

	Ft.	in.
(Shale).		
Coal	3	9
Shale	0	4
Coal	9	0
Shale	0	2
Coal	0	6
Shale	0	4
Coal	4	3
Total .	18	4

In certain bore-hole sections of this area, the seam is shown to be of a total thickness of as much as 30 feet.

The middle portion of the seam includes eight to nine feet of coal of good quality and, as was the case with the equivalent Jemeri-Raniganj seam to the west, this is the section usually extracted. Excluding the several feet of shale and shaly coal strata, which form the roof of the seam, the overlying beds include thick massive sandstones, contrasting in type with those shaly measures that overlie the Upper Kajora seam.

The Upper Kajora seam crops out to the east of the Kajora-Siduli strike-fault at Modhujori colliery and to the west of Khandra and Khas Kajora collieries. Further south, it is worked in depth in the pits of Central Kajora colliery, and again to the east near Dakshinkhanda and Mohira villages, though the workings of the latter colliery are now closed. West of the fault, the seam crops out again in the Parashkol tract and continues southwards across the eastern half of the Kajora

Upper Kajora seam.

colliery area. The details of the seam within certain of these collieries, are as follows:—

Modhujori colliery.

	Ft.	in.
Inferior *coal*	3	0
Good *coal*	9	0
Shale	0	2
Coal	0	7
Shale	0	2
Good *coal*	2	6
Shale	0	2
Inferior *coal*	4	0
Total	19	7

Darbhanga colliery.

	Ft.	in.
Coal	12	0
Band	0	6
Coal	4	0
Band	0	3
Coal	4	0
Total	20	9

Upper Kajora colliery.

	Ft.	in.
(Shale)	2	6
Coal	10	6
Shaly coal with shale bands	4	0
Coal and shaly *coal*	5	0
Total	22	0

Khandra colliery.

	Ft.	in.
Coal	11	0
Shaly sandstone	0	9
Coal	10	3
Total	22	0

Khas Kajora colliery.

	Ft.	in.
Coal	12	6
Shale	0	6
Coal	7	6
Total	20	6

Pure Kajora colliery.

	Ft.	in.
Coal	11 to 12	0
Shale	0	1
Coal	0	6
Shale	0	1
Coal	4	6
Shale	0	6
Coal	4	6
Total	22	2
	(approx).	

Real Kajora colliery.

	Ft.	in.
Good *coal*	11	0
Band	0	3
Coal	3	0
Band	0	3
Coal	4	0
Total	18	6

The seam is of a similar type in the Central Kajora area, and is distinguished from the Lower Kajora seam by the following characters :—

(i) Upper half of the seam is of the better quality and is normally extracted.

(ii) Alternating sandstones, shaly sandstones, and shales with thin coal seams overlie the seam.

In these respects it resembles the equivalent Siarsol seam.

Jambad-Bowlah seam.

The Jambad-Bowlah seam, the north-easterly continuation of the Lower Kajora and Sonachora seams of the Kajora area, is met with to the east of the Kajora-Siduli strike-fault, beneath the Upper Kajora seam of Khas Kajora colliery. Repeated to the north-west of this strike-fault, it is proved by borings beneath the Parashkol seam to include a total thickness of 42 feet. Further east, it is being worked to the north and south of the Kajora-Siduli-Bankola strike-fault within the collieries north of Siduli village, and at Sunkerpur and Bankola. The second strike-fault—the Shankarpur-Sitalpur fault and its suggested continuation to the south-west—again throws the seam down within the Parasia-Jambad-Bahula-Joteghemu (Jote Dhemo) colliery areas. It crops out in these localities and is being worked from a number of inclines and shallow pits. The details of the seam within these working are as follows :--

Khas Kajora colliery.

	Ft.	in.
(Massive sandstones).		
(Shale 5 ft.)		
Coal	19	6
Band	0	6
Coal	5	0
Sandstone	3	0
Shale	2	0
Coal	7	6
Shale	0	6
Coal	8	0
Total	46	0
Coal in seam	40	0

East Jambad colliery.

	Ft.	in.
(Sandstones).		
(Shale 4 ft. 3 in.)		
Coal	4	0
Band	0	5
Coal	7	0
Band	0	1
Coal	5	0
Band	0	6
Coal	7	6
Band	0	10
Coal	17	6
Total	42	10
Coal in seam	41	0

A. K. Patel colliery.

	Ft.	in.
(Sandstone).		
Coal	14	6
Shale	0	5
Coal	7	0
Shale	0	9
Coal	18	4
Total	41	0
Coal in seam	39	10

Sunkerpur colliery.

	Ft.	in.
Coal	4	6
Shaly sandstone	9	0
Coal	11	0
Band	2	0
Coal	23	6
Total	50	0
Coal in seam	39	0

South Jambad colliery.

	Ft.	in.
(Sandstone roof).		
Coal	5	0
Band	0	6
Coal	8	6
Shale	0	1
Coal	6	0
Shale	0	4
Coal	1	6
Shale	0	1
Coal	4	9
Shale	0	2
Coal	1	6
Shale	0	2
Coal	1	0
Shale	1	0
Coal	1	6
Shale	0	1
Coal	13	4
Total	45	6
Coal in seam	43	1

Bahula (Bow'ah) colliery.

	Ft.	in.
(Sandstone).		
Shaly *coal*	5	0
Band	0	6
Clean *coal*	12	0
Band	1	0
Clean *coal*	3	0
Band	0	2
Coal	0	8
Band	0	2
Coal	4	0
Clean *coal*	16	0
Total	42	6
Coal in seam	40	8

Bankola colliery.

	Ft.	in.
Coal	8	0
Stone	10	3
Shale	0	6
Coal	6	0
Shale	0	3
Coal	3	0
Shale	0	6
Coa	13	0
Total	41	6
Coal in seam	30	0

At Sunkerpur colliery, the lower 12- to 14-foot portion of the seam is being worked, and an 8-foot section of the lowest part of the seam is now extracted at Bankola. This portion of the seam is of very good quality, though higher sections are also of a workable grade and are being exploited in certain of the Jambad collieries.

Area east of Siarsol.

In the extreme west of the area under consideration, a coal seam, which the writer concludes to be the Raniganj seam, crops out in an abandoned quarry, about half a mile south-east of Siarsol village, just east of the Jamuria-Raniganj cross-fault. Its continuation to the east is not proved, though it is suggested that the seam would be found to underlie the massive sandstones to the west and north-west of Ronei village.

v. Andal-Dakshinkhanda sandstones and shales with thin coal seams.

These uppermost Raniganj measures include a sequence of alternating sandstone and shale strata, with several relatively thin coal seams, none of which have so far proved to be of any great economic importance. These strata are possibly represented in the bore-holes that have been put down to the south-east of Raniganj, and to the east of the fault that limits the eastern workings of Napur colliery. In one bore-hole of the latter area, a 19-foot seam was reported at a depth of about 218 feet. This seam might well be the Siarsol-Upper Kajora seam, for the overlying strata include a series of sandstones and shales with thin coal seams, suggestive of the uppermost Raniganj measures. Doubt is expressed regarding the exact correlation of the measures of Palashban and East Madanpur collieries to the west of Andal.

Palashban-East Madanpur collieries.

At the former colliery (now closed) a $12\frac{1}{2}$-foot seam was worked at a depth of about 123 feet. At East Madanpur colliery, two closely associated coal seams, including an upper 13-foot seam and a lower 8-foot seam, were reported.

Bore-holes located between this area and Palashban village are said to have proved a number of coal seams, including several of the order of 15 to 20 feet in individual thickness. It is difficult, however, to correlate these seams with those of upper Raniganj beds of the neighbouring areas to the north, and from the evidence afforded by the limited number of bore-holes, it is impossible to suggest the geological structure that exists beneath the thick

alluvial capping of these tracts. The main southern boundary-fault of the coalfield probably runs at no great distance to the south, and it is quite possible that lower measures of the Raniganj series are again brought up in the form of a sharp synclinal, or that large faults, effecting similar results, traverse the area.

Area north of Andal.

To the north of Andal, between Kajora village and Dakshinkhanda, and in the vicinity of Khandra village, however, the uppermost Raniganj rocks certainly crop out beneath the alluvium and are overlain by the Panchets to the south-east. These uppermost coal-bearing measures have been proved in the deep bore-hole to the south-east of Central Kajora colliery, in a bore-hole located about one mile north of Dubchururia, and in others near Dakshinkhanda and Mahira (Mohira). They include several relatively thin coal seams, one of which attains a thickness of eight feet in the Mahira area. None of these seams have, however, been worked. (*See* Plate 18.)

V.—Semalya (Samla)-Purushottampur-Jhanjra area.

In Dr. Blanford's geological map, the Gondwana outcrops of this area were unfortunately coloured as Barakar, though the legend letter for the Raniganj beds is printed. Dr. Blanford calls attention to this mistake in his Errata (p. viii). The error has unfortunately been repeated in certain of the more recent maps.

No doubt, however, exists regarding the inclusion of these measures within the Raniganj series. Both the general lithology of the sequence, the nature of the coal seams and the geological structure of the Gondwana tracts adjoining the Adjai river, point to this conclusion. The measures are bounded on the south-west by the continuation of the Adjai river fault, which, with a downthrow to the north-east to the extent of several hundred feet, causes the lower Raniganj strata to crop out against the Ironstone Shales of the Bhuri village area.

Structure.

The general dip of these rocks is to the south at relatively gentle angles. A short distance to the south of the Adjai, the strata are completely hidden beneath a capping of laterite and alluvium, and the structure, which appears to be complicated by a number of large faults, can only be partially elucidated on the evidence of the existing colliery and bore-hole records. The basal Raniganj rocks apparently extend beneath the Adjai river and overlie the Ironstone Shale beds, which

occur beneath the alluvium to the north, whilst the uppermost measures have been proved by bore-holes to crop out beneath the laterite and alluvium within the Bansia-Jhanjra area. The Raniganj rocks doubtless continue beneath these recent and sub-recent deposits at least for a considerable distance to the east of the Gobindapur (Govindpur)-Darula-Bansia tract. The areas were geologically mapped by Messrs. Banerji and Auden, from whose reports much of the information given below is derived.

Lateral variation in lower measures.

Reference has already been made to the marked thinning of the basal Raniganj measures and lowermost coal seams within the eastern part of the coalfield. The writer is of the opinion that this diminution in thickness continues to the north-east and that within the Semalya-Gobindapur (Govindpur) area the basal measures and included coal seams of the Chichuria tract, have died out completely. At the time of their deposition, the basal Raniganj strata of the latter area were continuous with those that overlay the Ironstone Shales of the Bhuri area, about three miles north of Chichuria. This indicates a decided overlap of the middle Raniganj rocks to the north, and suggests the possibility of the occurrence of the lowest Raniganj strata in greater thickness beneath the higher measures to the south. As Mr. Auden remarks :—

'In this connection the overlap of the Barakars over the Talchirs, and of higher Barakars over lower Barakars (within the area north of the Adjai) is suggestive, since it occurs in the same relative position within the coalfield.'

No intrusive rocks have apparently been met with in the Semalya-Jhanjra area.

The Raniganj strata of this extreme north-eastern portion of the coalfield have been divided into the following stages, roughly equivalent to those of the Tapasi-Sonpur-Andal area.

iv.-v. Upper coal measures of the Jhanjra-Konardihi area.
iii. Kendra-Purshottampur coal measures.
ii. Semalya sandstones and shales (about 150 feet).
i. ? Absent.

The details of these various stages are as follows :—

ii. Semalya sandstones and shales.

The rocks of this stage include the sandstone and shale strata that underlie the Samla coal seam (of the base of stage iii) in the vicinity of Semalya village, and which doubtless continue eastwards to the north of the Adjai beneath the alluvium of the Bara-

jora locality, and underlie the northern half of the river to the south of Ratanpur. A bore-hole (Plate 18, bore-hole 69) located a short distance south of the railway-siding to the south of Kendra village, proved these sandstone and shale beds to include a thickness of about 138 feet, beneath which thick carbonaceous shales were met with. These shales, 57 feet of which were passed through in the base of the bore-hole, are regarded by the writer as representing the uppermost beds of the Ironstone Shale series. In the Gobindapur area, a succession of similar shales was proved about 150 feet below the Samla seam, whilst in a bore-hole at Abhirampur, shales with 'limestone' bands were met with at a depth of about 280 feet below the Samla coal seam. This latter bore-hole is located to the dip of the two former holes and suggests that these basal Raniganj beds thicken to the south.

iii. Kendra-Purushottampur coal measures.

Section at Purushottampur.

These measures include the coal seams that are now being exploited within the area. Near Purushottampur colliery, the lower beds of this stage comprise, in descending order:—

	Ft.	in.	
Coal seam	12	6	
Strata	170	0	
Coal seam	21	0	(Purushottampur seam).
Strata	128	0	
Coal seam	17	6	(Samla seam).

In other bore-holes, a fourth coal seam, about 12 feet in thickness, overlies the 12½-foot seam by about 75 feet. These two upper 12½-foot seams and the 21-foot Purushottampur seam, agree quite well with the similar coal seams proved within the Shankarpur-Hansdiha area to the west. The details of these coal seams within the various collieries are as follows:—

Samla seam.

The Samla seam cropping out within the inclines of Semalya (Samla) colliery, to the south of the Adjai river, is intercepted by an oblique cross-fault to the east at Chhatrishganda village. Mr. Auden suggests that this fault is of a downthrow of at least 400 feet. For some distance to the east, the coal seam apparently underlies the alluvium to the north of the Adjai river and has been worked from shallow pits at Barajora colliery. Further east, the Samla seam apparently crops out in a south-easterly direction beneath the Adjai, but to

the north of Gobindapur it again encroaches on the southern side to the river and continues for an unknown distance to the north of Konda and Nutandanga villages. East of this Chhatrishganda fault, to the south of the Adjai, the coal is worked at a number of collieries and, affected by several faults within the Darula-Purushottampur tract, it is again met with at a shallow depth a short distance south of Mahal village. A large fault throwing down to the north-west, appears to traverse the measures about half a mile west of Mahal, causing the seam to be buried to a much greater depth within the area south of Baidyanathpur. The seam is relatively uniform in occurrence, ranging normally from 15 to 18 feet in total thickness, though in the shallow workings of Barajora colliery north of the Adjai, a thickness of 14 feet was reported. The section of the seam is as follows:--

	Ft.	in.
Coal	7	0
Band	0	9
Coal	9 to 10	0

Shaly partings are recorded within the upper section of the seam, and occasionally within the lower. This lower section of the Samla seam is, apparently, of the better quality and is normally extracted. The coal is of good quality, though high in moisture, and includes alternating bands of vitrain and durain. Within the latter, nodules of iron pyrites are of frequent occurrence.

Purushottampur seam.

The Purushottampur seam is met with in the shafts of Purushottampur colliery (now closed) at a depth of about 150 feet and is separated from the underlying Samla seam by about 140 feet of unproductive strata. The seam is of a total thickness of 21 feet of which the upper four feet and the lower three feet are of a distinctly inferior quality. The intervening section of the seam is apparently of moderate quality and has been worked in the past. Several faults appear to intersect the measures of this locality. The Purushottampur seam is proved within the bore-holes of the Baidyanathpur and Abhirampur areas to the north, where it undergoes considerable lateral change (*see* Plate 18, bore-holes 65 to 68). Within these latter areas, the seam splits up into a number of thin coal seams which, in the Ramnagar-Kendra area, are represented by a total thickness of coal, shale and shaly sandstone of about 14 feet, separated from the underlying Samla seam by about 148 feet of strata, mainly of sandstone type.

Bhatmura and Jhatarbad collieries.

To the west of Purushottampur, at Bhatmura and West Kumardihi collieries the following coal seams have been proved within shallow pits :—

	Ft.	in.			Ft.	in.
Top seam	9	0				
(Strata)	50	0				
Bottom seam	7	6		*Coal*	4	6
				Band	1	6
				Coal	1	6

The seams appear to be of inferior quality and only the lower 6-foot section of the Top seam was being extracted. A short distance to the south, at Jhatarbad colliery a 13 ft. 6 in. seam was proved.

The exact correlation of these latter coal seams with those of the more western areas is obviously impossible owing to the lack of connected sections and the probability of large faults within the locality. It is tentatively suggested, however, that they may represent certain of the inferior coals, of approximately Bonbahal horizon, which are included within the middle Raniganj measures to the north of Shankarpur.

Correlation with the western areas.

Regarding the exact correlation of the lower Raniganj measures of the Semalya-Gobindapur-Purushottampur area with those of the Tapasi-Sonpur localities to the south-west, there is an element of uncertainty. The area is complicated by a number of faults including the large Chhatrishganda fault. From the available evidence of borehole and colliery records, however, the writer is personally convinced that the Samla-Kendra seam of the north-east represents the easterly continuation of the Dobrana seam of the more western areas. His reasons for arriving at this conclusion are as follows. The section of the lower Raniganj strata about the longitude of Chichuria is :—

	Ft.	in.	
Kenda-Chora seam	25	0	(thinning to the east).
Strata 150 ft. (approx.)			
Dobrana seam	16 to 18	0	
Strata 300 ft.			
Chichuria seam	8	6	
Strata 96 ft.			
Dahuka seam	5	9	
Strata 46 ft.			
Coal	1½ to 2	0	
Sandstones and shales 376 ft.			
Shales with ironstones. (Ironstone Shale measures.)			

It has been previously observed that a rapid thinning of the lowest Raniganj strata has taken place between Shibpur and Chichuria, and that the included coal seams also decrease considerably

in thickness. It would therefore not be surprising to find that these lowest coal seams had died out entirely further east. Noting the succession above the Chichuria coal seam, in the vicinity of Hansdiha, a 23-foot seam has been proved in depth and this appears definitely to represent the easterly continuation of the Chora seam. To the north-east, the coal seam at Sonpur colliery is in all probability the same seam. Borings at Purushottampur to the east, prove fairly clearly that the 21-foot seam of that colliery is the equivalent of this Chora-Sonpur seam. The quality is similar, and indeed it would be very difficult, necessitating rapid lateral changes in the coal seams, to suppose it to be any other. The two 12-foot seams above this 21-foot seam also bear out this correlation, they being equivalent to those of approximately Bonbahal horizon within the area south of Hansdiha. Allowing, therefore, that the Chora Sonpur-Purushottampur 21-foot seams are the same, it is more than probable that the 16- to 17-foot seam, which has been proved to occur about 150 to 170 feet below it at Purushottampur, is the equivalent of the Dobrana seam of the Chora-Hansdiha locality. This 16- to 17-foot seam of the Purushottampur area is worked at a number of adjoining collieries and there is good reason to suppose that it is the equivalent of the Samla seam, worked further to the rise in Kendra and Gobindapur collieries. This reasoning is also borne out by the borings of that locality (*see* Plate 18, bore-holes 61 to 70). Bore-holes in the vicinity of Purushottampur show that the 21-foot Purushottampur-Chora seam is liable to split into several thinner seams. In certain bore-holes of the Abhirampur *mouza*, this splitting-up of the seam is accompanied by a decrease in thickness, as is also the case in the Baidyanathpur *mouza*, where the 17-foot seam—undoubtedly the equivalent of the lowest seam of Purushottampur colliery adjoining, and of the Samla-Kendra collieries to the north—is met with 130 to 170 feet below this group of thin seams. The bore-hole that has recently been put down to the dip of Kendra colliery (*see* Plate 22, bore-hole 69) proved the following succession:—

Recent bore-hole near Kendra.

	Ft.	in.	
Several thin *seams* separated by bands of shale and shaly sandstone, in all	14	0	(Purushottampur-Sonpur seam).
Mainly sandstones	148	6	
Coal	17	0	(Samla seam).
Sandstone and shale	7	6	
Coal	1	1	
Sandstones and shales alternating	80	0	
Shales and shaly sandstones	50	0	
Black and grey shales	37	0	
Black micaceous shales	20	5	

Abhirampur bore-hole. In the Abhirampur *mouza* the following succession was passed through:—

	Ft.	in.	
Coal	15	0	(Purushottampur seam).
Mainly sandstones with shales . . .	135	0	
Coal	16	0	(Samla seam).
Sandstones and shales, with shales including 'limestone' bands at the base .	288	0	

It seems reasonable to conclude that the Ironstone Shales were penetrated in the bottom of these bore-holes and that the 'limestone' bands in the Abhirampur section were, in reality, bands of unoxidised clay ironstone. Unfortunately, the writer was away from the field at the time the Kendra boring was put down—in 1928—but Mr. Penman very kindly kept specimens of the cores for a later examination. The black shales in the lower part of the bore-hole resemble those of the Ironstone Shale measures very closely. From the above description the writer can but conclude:—

Conclusions regarding correlation.

1. The Chora Sonpur-Purushottampur 25- to 21-foot seams are equivalent.
2. That the Purushottampur 21-foot seam splits up to the north-east and north and decreases in thickness.
3. That the Dobrana seam = the 17-foot Purushottampur seam = Samla seam.
4. That the lower group of seams met with in the Chichuria area below the Dobrana, die out to the north-east, and that the accompanying strata also thin considerably, so that in the Ramnagar and Abhirampur areas the Ironstone Shales are met with 150 to 250 feet below the Samla seam.

Should the thick black shales at the base of the Kendra bore-hole prove to belong to the lower Raniganj measures and not to the Ironstone Shale series, and should the continuation of the Chichuria group of seams be found below them, this will only lend additional support to the above conclusions regarding the correlation of the Samla seam.

iv.-v. Upper coal measures of the Jhanjra-Konardihi area.

There is no doubt that the upper measures of the Raniganj series underlie the laterite and alluvium within the Konardihi-Sarpi-Jhanjra area. Bore-holes to the north of Sarpi, at Shyamsundarpur, and at Jhanjra to the east, have proved a sequence of coal measures comparable to those of the more western parts of the coalfield (*see* Plate 18), though without further information

it is impossible to state with any degree of certainty the exact correlation of the individual coal seams. Further north, at Moldanga colliery, a seam of a total thickness of 30 feet, comparable to that of the Bankola seam, has apparently been worked at a depth of about 200 feet. This correlation is borne out by the evidence of a bore-hole located near the colliery. Within this bore-hole the following coal seams were proved :—

Moldanga colliery.

	Ft.	in.		Ft.
Coal (Bowlah seam)	33	6	at a depth of	194
Coal	13	0	" "	375
Coal	9	6	" "	447
Coal	5	6	" "	496
Coal	5	4	" "	557
			Total depth of bore-hole	600

From the evidence of the adjoining tracts to the west, it is suggested that these southern areas of upper Raniganj measures are also affected by several large displacements.

Regarding the measures further east, a bore-hole was reported to have been put down near Tilabani village, and to have proved the following succession of coal seams :—

Bore-hole at Tilabani.

	Ft.	in.		Ft.
Coal seam	2	6	at a depth of	63
" "	3	0	" "	123
" "	13	0	" "	174
" "	11	0	" "	318
" "	5	0	" "	397
" "	18	0	" "	517
" "	52	0	" "	712

No authentic information could be obtained regarding this bore-hole and until the succession is confirmed by further explorations the details of these apparently very productive measures must be regarded as doubtful.

Further east, a bore-hole was also reported to have been put down near Madhaiganja village and to have proved a succession of sandstones and red shales in the upper part of the section, a 3-foot seam of coal being encountered at a depth of 470 feet. Should these bore-holes prove correct, they indicate the existence of a large cross-fault, throwing down to the east, and separating the measures of the Bansia-Tilabani area from those of Madhaiganja.

Bore-hole at Madhaiganja.

Summary of Correlation of Coal Seams.*

For the purpose of correlation it is of course necessary to select some standard horizon that can be recognised over a wide area.

Constant horizons for the purpose of correlation.

In the western and middle portion of the coal-field, from the Barakar river to the longitude of Damodarpur, the Sanctoria-Poniati seam, together with the Dishergarh seam above it in the western half of this area, form a sound basis for correlation. There is no reason to doubt the equivalence of the Sanctoria and Poniati seams, and above this horizon the middle and upper Raniganj coal seams fall into line fairly satisfactorily. In addition to the sequence of the beds, the character and quality of the seams are also taken into account. East of Damodarpur, however, the Poniati seam and its associates in the lowest Raniganj measures, decrease in thickness and deteriorate in quality, so that they cannot be recognised individually with any great degree of certainty. In the case of the upper Raniganj seams, however, the most decided lateral changes occur about the longitude of Asansol and Kalipahari, and east of this area two closely associated coal seams, the Ghusick-Siarsol seam and the Nega-Raniganj seam, come in and remain constant in character and thickness as far east as the longitude of Andal, well east of the Damodarpur area, whilst the upper one, the Siarsol-Upper Kajora seam, persists also in the extreme eastern part of the field. In the eastern area, therefore, these uppermost seams have been taken as the basis of correlation with very satisfactory results. (*See* Plates 17 and 18.)

I.—Gangutiya-Taltor seam.

The Gangutiya seam is said to be five feet thick and to occur in the lowest Raniganj measures about 400 feet from the base and

Gangutiya seam.

about 100 feet below the Sanctoria seam, of the Dishergarh area. No information regarding this seam is available further east until we reach the Charanpur area, where a seam of coal, about four feet thick, named locally the Taltor seam, has been met with about 200 feet below the Poniati

Taltor seam.

seam and 450 to 500 feet above the base of the Raniganj measures. These facts at least indicate that the Gangutiya and Taltor coal seams occur at approximately the same horizon in the lowest Raniganj measures, though

* *See* Plates 17 and 18, and Tables of analyses on pp. 273-277.

whether they represent portions of one and the same seam, it is, owing to the lack of information in the intervening tract, impossible to say. The seam appears to continue eastwards at about the same depth below the Poniati and is first worked to the north-east of Nandi village. Further east in the Sekpur area, the Taltor seam thickens to six feet and occurs at a depth of only 160 feet below the Poniati seam. No evidence is available regarding this lowest seam of the measures to the dip of the above-mentioned areas except in this eastern part of the field. In the latter area, however, within the Banali *mouza*, a 2 ft. 9 in. seam is proved by boring to exist about 150 feet below what is probably the Poniati seam. Again in the Palasdanga area further east, bore-holes appear to have reached the Taltor seam, but the evidence here is somewhat confusing for in this area the seam above, which is regarded as the Poniati seam, has thinned to about the same thickness as the Taltor—4 to 6 feet—and since these bore-holes do not penetrate to the Ironstone Shales we have no really definite horizon for correlation. Across the faulted area between Sekpur and Dhasul, lack of information prevents one from establishing a detailed correlation; all that can be safely stated is that the coal seams of the Mahmudpur area, including three seams from 4 to 8 feet thick, belong to these lowest Raniganj measures, and can be tentatively correlated with the Koiti, Poniati and Taltor seams. Further east in the Chichuria-Dahuka area the seam may be represented by the lowermost coal-horizon, varying from 1½ to 2 feet in thickness (*see* p. 228).

Banali-Palasdanga area.

Mahmudpur area.

II.—Sanctoria-Poniati seam.

In the Sanktorya (Sanctoria) area of the western part of the field, the Sanctoria seam is about 10 feet in total thickness. To the south of the Damodar river, it is represented, about six feet in thickness, in the old inclines of the Nadiha-Chaurashi (Chowrassi) area. East of the Sanctoria workings for a distance of several miles the seam is apparently intruded into by mica-peridotite, and largely converted to *jhama*. The geological structure and lithology of this undisturbed area, however, points to the conclusion that the lowest seam of the workings of Chichuria colliery to the north of Asansol, is the equivalent of the Sanctoria to the west. This is further corroborated by the rela-

West of Asansol.

tion of this seam to the Dishergarh seam, which can be followed with certainty across this tract and which occurs about 350 feet above the assumed Sanctoria seam in both areas. At Chichuria colliery, the Sanctoria seam is 12 ft. 6 in. thick. Separated by faults from the Jayramdanga-Barabani area, it appears to increase in thickness within these areas east of Chichuria, where it continues under the name of the Poniati seam about 18 feet thick. Here it again includes the characteristic lenticular bands of coarse-grained ironstone. The sequence is so regular and the quality of the seam so constant that there can be no doubt regarding the continuity of the Poniati across the faulted tract of Barabani and Charanpur into the Shibpur-Damodarpur area. In this latter area it is sometimes termed 'the Shibpur seam'. In the Damodarpur-Sekpur tract it shows lateral variation, thinning to the east and to the dip to about four feet and, as a result, it is difficult to distinguish from the associated Taltor and Koiti coal seams. Further east, it may tentatively be correlated with the middle seam of the Mamudpur area and the 5 ft. 9 in. seam of the Chichuria-Dahuka areas, known locally as the Dahuka seam (*see* p. **228**).

East of Asansol.

III. Hatinal-Koiti seam.

About 132 feet above the Sanctoria seam of the Sanktorya (Sanctoria) area is the Hatinal seam, nine feet thick, but of a quality considerably inferior to the Sanctoria and Dishergarh seams. At Chichuria colliery, it is again proved 175 feet above the Sanctoria and about 200 feet below the Dishergarh seam. This alone suggests that it is the exact equivalent of the Hatinal to the west. It is of relatively poor quality, but like the Sanctoria-Poniati seam it increases in thickness and improves in quality to the east in the Jayramdanga-Barabani area. In this area, under the name of the Koiti seam, about 12 feet in thickness, it is worked at a number of collieries. Again, like the Poniati seam, it thins to the southeast of Kaithi village, and further east is apparently of no present economic value. In this eastern area, it appears to have thinned to the dip also, and in some instances to have split up into a number of thin coaly bands. As has been previously noted, the Koiti seam is possibly represented further east by the Dhasul-Chichuria seam, proved to be 8 ft. 6 in. thick within the workings of the Chichuria area (*see* p. **228**).

IV.—Dishergarh, Chowkidanga, Dobrana and Samla seams.

Dishergarh seam.

The Dishergarh seam—the most important coal seam of the Raniganj measures in the western part of the field—is met with 214 feet above the Hatinal seam in the Sanktorya (Sanctoria)-Dishergarh area. It is from 16 to 18 feet thick, but increases to 20 feet a short distance to the east. To the south-west, across the Damodar river, it can be followed through the workings of Saltor, Deoli and Nadiha to Puapur; its thickness in the latter locality being only about nine feet. East of Dishergarh, its outcrop can be traced almost continuously into the Chichuria area to the north of Asansol, across which tract of country a fairly gradual decrease in thickness is noted, the seam being only eight feet thick at Chichuria colliery. East of Chichuria, this change is more rapid and to the south of Jayramdanga the seam is proved to be only 3 to 4 feet thick. There appears to be no doubt that this 3- to 4-foot seam represents the Dishergarh of the west, for the Sanctoria-Poniati and the Hatinal-Koiti seams below form very constant horizons for the purpose of correlation and the overlying strata fall into line. To the dip, in the Majiara area, what is probably the equivalent of the Dishergarh seam is shown in one deep bore-hole to be 6 ft. 6 in. thick, occurring at an horizon about 300 feet above the Koiti and 500 feet above the Poniati, but in the adjoining tracts to the east, at about the same horizon, a seam only three feet thick is met with and in some instances this appears to be represented by several very thin seams up to two feet in individual thickness. Bearing in mind the character and importance of the Dishergarh seam of the west, it would be unfair and unreasonable to designate either of these thin coal seams of the middle portion of the field by the same name. That they occur at *approximately* the same horizon within the lower Raniganj measures as does the Dishergarh seam of the west is doubtless true; equally true, however, is the fact that the Dishergarh seam of the western part of the field—a seam of excellent quality and considerable thickness—does not exist as such to the east of Chichuria colliery. It may die out completely and the thin seams, which occur about the same horizon further east, may be quite distinct seams; on the other hand, it may be represented eastwards by one of these thin inferior coal seams.

To the south of Shibpur, a 6-foot seam is met with 300 feet above the Koiti seam, and to the dip in the Ningah-Banali tract, a seam of similar thickness is encountered about this 'Dishergarh' horizon.

It is, however, of poor quality, and from the evidence of the bore-holes, somewhat inconstant. Within the area north-west of Tapasi (Toposi), however, one of these relatively thin seams, at an horizon about 300 feet above what is probably the representative of the Koiti-Poniati-Taltor group, thickens to 11 feet and is locally termed the Chowkidanga seam. It increases in thickness to 16 feet as the Jote Janaki seam and eastwards to 18 feet as the Dobrana seam. The 30-foot Toposi-Kenda seam above it, forms a basis for this correlation as does the 8-foot Dhasul-Chichuria seam below. That this Chowkidanga-Jote Janaki-Dobrana seam of the east occurs at *about* the same horizon as the main Dishergarh seam of the west is doubtless correct, but to suggest that it is the direct easterly continuation of the Dishergarh would be overstating the case. The **Dobrana** seam is, in the opinion of the writer, represented by the Samla seam of the extreme north-eastern corner of the coalfield (*see* p. 243).

Chowkidanga-Samla seam.

V.—(a) Bara Dhemo. }
(b) Raghunathbati } *Manoharbahal-Rana-Poriarpur-Satgram-Toposi-Kenda-Chora-Purushottampur seam.*

This seam, or rather group of seams, comprising two closely associated coal seams in the western portion of the field, is very constant over certain areas. Considerable lateral changes in thickness and in quality do occur, however, particularly to the west of Manoharbahal where the two separate seams (*a*) and (*b*) run together, and again between Satgram and Toposi where the seam increases rapidly in thickness. The evidence in favour of the above correlation is, however, fairly conclusive.

Lateral changes in coal seams.

To the north-west of Asansol within the Raghunathbati-Sarakdih locality, two closely-associated coal seams crop out at an horizon varying from 450 to 530 feet above the Dishergarh seam. These two seams include in ascending order:—

V. (*a*) Bara Dhemo seam (10 ft.).
(Strata 70-80 ft.).
V. (*b*) Raghunathbati seam (4 ft. 6 in.).

To the south-west of Lachhipur colliery, these two coal seams run together and are represented by one seam of shale and coal of very inferior quality.

Again, east of Sarakdih, at Manoharbahal and Bara Pukhuriya, the two coal seams appear to combine to form the Manoharbahal seam of a thickness of eight feet. At Manoharbahal colliery the seam occurs about 450 feet above the Dishergarh; but to the dip, bore-holes indicate that these intervening strata have increased to nearly 600 feet. In the Majiara tract to the east, the seam is unworked, but has apparently been passed through in several bore-holes in which it varies in thickness from 5 to 6 feet. Further east, however, to the south of Charanpur, within the Rana area, a seam—locally called the Rana seam—is worked at Rana colliery. This seam, of a thickness of about eight feet, is proved by bore-holes to occur at an horizon about 870 to 900 feet above the Poniati seam. Across the faulted area to the south-east of Rana colliery, a 9-foot seam is met with at about the same horizon—920 feet—above the Poniati seam. This seam, termed locally the Poriarpur seam, was regarded by Mr. Walker as being distinct from and younger than the Rana seam, but it is probable that the Rana bore-hole, which reaches down to the Poniati seam, was not at that time available.

Manoharbahal seam.

Rana seam.

Poriarpur seam.

The Poriarpur seam is again met with near the outcrop at Shripur colliery and continues south-east to Joba and Banali where it has increased to 12 feet in thickness. Although disturbed by a number of minor cross-faults, the seam can be followed with certainty across the Banali area to Satgram where it has increased to about 15 feet in total thickness, including two feet of shaly coal at the top. The large Jamuria-Siarsol dip-fault, with the possibility of other faults further east, cuts off the Satgram-Poriarpur seam to the east at Satgram. There is no record of the Satgram seam within this faulted tract, the Balanpur bore-holes being, apparently, situated too far to the north. There is, however, no reason why the seam should not be met with, probably between Bijpur and Katagaria. This lack of bore-hole or colliery information between Satgram and Tapasi is all the more unfortunate since considerable lateral variation appears to take place in the lower and middle Raniganj measures within these localities. We have seen that the Poriarpur-Satgram seam showed a decided tendency to increase in thickness to the east. Taking the constant Ghusick-Siarsol seam of the uppermost Raniganj measures as the horizon for correlation, it is observed that the Poriarpur-Satgram seam occurs about 750 to 800 feet below. In the

Satgram seam.

Siarsol-Tapasi area the strata intervening between the Siarsol seam and the Toposi thick seam are about 800 to 850 feet in thickness. This alone indicates that the Satgram and the Toposi seams are equivalent, and to suggest a different correlation would necessitate the dying-out of the Satgram and the incoming of the thick Toposi seam within a comparatively short distance. Like the Satgram seam, the Toposi seam is also found to thicken to the east and north-east. In the west of the Tapasi area, near its line of outcrop, it is apparently 19 feet thick, while to the east, at Toposi colliery, it has increased to at least 30 feet. Further east, there is no reason to doubt the equivalence of the Toposi and the 30-foot Kenda seam. Still further east, it continues as the Chora seam of slightly diminished thickness, whilst its correlation with the Sonpur and Purushottampur seams (21 feet thick) is more than probable (*see* p. 243).

Toposi seam.

Kenda-Chora seam.

VI.—Nadiha-Shripur-Singaran seam.

Near Nadiha village, to the north-west of Asansol, a 3-foot seam occurs about 120 feet above the Raghunathbati seam. At about the same horizon, to the north-east of Asansol, one or more thin seams are met with in bore-holes and shaft-sections, whilst further east in the Shripur area, a seam of inferior quality, 7 to 9 feet thick, and occurring at a similar horizon, becomes more constant and is locally termed the Shripur seam. The seam continues within the Satgram area, about nine feet in thickness, and 120 to 160 feet above the Banali-Satgram seam. At Singaran colliery near Tapasi, an 8-foot seam of inferior quality crops out about 200 feet above the thick Toposi-Kenda seam, and is probably the equivalent of the Shripur seam of the west. Further east, this 8-foot seam may be represented by the Bonbahal seam, though it is possible that this latter seam, which is about 220 feet above the Kenda-Chora seam, may represent a slightly higher horizon within the Raniganj measures.

Shripur seam.

VII.—Lower Dhadka-Nega-Raniganj Narrainkuri } Lower Kajora Sonachora } Jambad-Bowlah seam.

From 350 to 400 feet above the Raghunathbati-Manoharbahal seam to the north of Asansol, is an 8- to 10-foot seam, known locally as the Lower Dhadka seam. The seam appears to vary somewhat in thickness and to

Lower Dhadka seam.

include several shale bands. It is of relatively poor quality. To the south-west, this coal seam is represented by several thin seams of coal and shale, while to the east, in bore-holes at Majiara, it is in one instance replaced by a 6 ft. 6 in. seam and a short distance away by several thin seams. To the east of the Banbishnupur-Mohishila cross-fault, several thin seams ranging from 3 to 6 feet in individual thickness, come in about this horizon. A short distance further south-east in the Ratibati-Chapui area, these seams appear to run together to form the 19-foot Nega seam. South-east and east *via* Jemeri and Nimcha, it continues as a seam about 21 feet thick including shale bands. The seam is here very constant and the writer has no doubt regarding its continuity. It is overlain by massive white and greenish-grey sandstones and is succeeded about 200 feet above by the Ghusick-Siarsol seam. West of the Jamuria-Raniganj cross-fault, it is represented by the lower seam of Raniganj colliery, under the name of the Raniganj seam. Both this seam and the 19-foot Siarsol seam above it remain very uniform for some distance to the east and north-east. The Raniganj seam forms the main coal seam of Babuisol colliery and of Mangalpur, and is equivalent to the lower 20-foot seam of the Kajora area, where it is known as the Lower Kajora seam. This correlation is based on the following characters:—

Nega seam.

Raniganj—Lower Kajora seam.

(*a*) The thickness, section, and quality of the seams are the same, the middle and lower part of the seam being of better quality than the topmost portion.

(*b*) It continues at a fairly constant horizon in relation to the Siarsol-Upper Kajora seam 150 to 200 feet above it; and the intervening strata are almost wholly massive sandstones.

(*c*) Beneath this seam, from the neighbourhood of Egara up to Kajora, and separated from it by about 80 to 100 feet of strata, largely of sandstone type, is an 8- to 9- foot seam, the Narrainkuri-Bansra-Sonachora seam.

Throughout the greater part of the Kajora area these two coal seams, the Lower Kajora 20-foot seam and the Sonachora-Bansra 9- to 12-foot seam are met with; but at the eastern end of the Kajora area, about 220 feet below what is definitely the Upper Kajora-Siarsol seam, a 40-foot seam (including stone bands) comes in. From the evidence of the bore-hole sections of that area, this 40-foot Jambad seam appears definitely to represent the combined Lower Kajora and the Sonachora seams. This is again proved fairly

Jambad-Bowlah seam.

conclusively by the bore-holes at Siduli. The Jambad seam has been exploited over a large area, and from the evidence of the seam itself, and of the accompanying strata, there seems no doubt that it continues to Sunkerpur colliery as the Bowlah seam and further east into Bankola as the Bankola seam. So far, except at Moldanga, just east of Bankola, it has not been developed in this extreme eastern part of the field.

VIII.—Bora Chak-Ghusick-Siarsol-Upper Kajora seam.

From 200 to 250 feet above the Lower Dhadka seam to the north-west and west of Asansol, is a seam of coal, about 10 feet in thickness and of fair quality—the Bora Chak seam. This coal seam continues westwards to the Damodar river at about the same horizon within the Raniganj stage. It is probably again represented in the small workings near Parbeliya and Murulia, to the south of the river. To the east of Asansol in the Majiara borings, it appears to be represented by a 4 ft. 6 in. seam, and near Kankhaya by two closely associated seams. As was noted in the case of the Lower Dhadka seam, considerable variations take place in these coal seams within this locality, and it would be unreasonable to press the correlation of the individual seams. To the south-east of the Banbishnupur (Bonbistopur)-Mohishila fault, however, at approximately the same horizon in the upper Raniganj measures, the Ghusick seam is met with. One can only state that this Ghusick seam comes in at about the same horizon in the upper Raniganj beds as does the Bora Chak of the western part of the field, but whether it is the exact continuation of the Bora Chak seam it is impossible to say. The Ghusick seam is at first represented by two distinct seams, the upper one, about 11 feet thick, being of good quality. The lower seam—Ghusick 'A'—is composed largely of shaly coal and shale. The upper seam is immediately overlain by thick shales and shaly sandstones with alternating sandstones and shales including several thin coal seams above. Further south-east, these two seams, which comprise the Ghusick, run together to form a 19-foot seam —the Siarsol seam. The seam continues about 150 to 200 feet above the Nega seam to Siarsol and Raniganj collieries. Further east in the Kajora area, it is doubtless represented by the 20-foot Upper

Bora Chak seam.

Ghusick seam.

Siarsol seam.

Upper Kajora seam.

Kajora seam. This is well established by the similarity of the seam itself, and of the strata above and below, and is illustrated in the bore-hole sections of the Central Kajora, Khandra, Mohira, and Dakshinkhanda areas (*see* Plate 18). It is the uppermost workable seam of the Raniganj stage in this eastern part of the coalfield.

Kushadanga seam.

In the Kalipahari area, about 150 feet below the Ghusick seam is an 8-foot seam of inferior quality—the Kushadanga seam. This seam appears to be only locally developed, and to die out to the east.

IX.—Gopalpur - Upper Dhadka-Satpukhuriya seam.

Gopalpur - Upper Dhadka seam.

About 200 feet above the Bora Chak seam to the west of Asansol, the 4 ft. 9 in. Gopalpur seam is met with. This seam appears to continue in thickness to the south-west, into the Bharat Chak area, where it is again proved to be 4 ft. 9 in. thick and to occur about 230 feet above the Bora Chak seam. To the north-north-east of Asansol, a seam at approximately the same horizon within the upper Raniganj measures is met with, and includes:—

	Ft.	in.
Coal	4	0
Band	2	6
Coal	4	0

It is locally known as the Upper Dhadka seam.

Satpukhuriya seam.

The same coal seam has been met with in the faulted area near Kalla colliery to the east, and again at Satpukhuriya where it has a total thickness of 9 ft. 6 in. with a band varying from 6 in. to 2 ft. in the middle. The seam at Satpukhuriya approaches the Ghusick in quality and composition and, as a result, these two seams have been regarded by certain of the local mining authorities as one and the same coal seam. The two areas are separated by the large Banbishnupur (Bonbistopur)-Mohishila cross-fault. For the following reasons the writer regards these two seams as distinct from one another:—

(i) A bore-hole to the west of this fault, east of Asansol, proves a 4 ft. 6 in seam about 365 feet above a 9-foot seam of 'shaly coal,' the latter including a 1-foot shale band in the middle. There seems little doubt that this 4- to 4½-foot seam is the equivalent of the 4-foot seam that has been worked in the inclines to the south-west of Satpukhuriya, and which definitely occurs 340 to 350 feet above the 9½-foot seam of Satpukhuriya

colliery. In this 'Asansol' boring the equivalent of the Ghusick seam is met with about 205 feet below this nine feet of 'shaly coal.' Again, in the Kumardih area just south-east of Kalipahari, a 7-foot seam of inferior quality is met with about 220 feet above the Ghusick seam.

(ii) Within the area west of the Mohishila fault, the uppermost strata of the Raniganj measures are of fairly constant thickness, the lowest Panchet beds coming in about 200 feet above the above-mentioned 4-foot seam, that is to say, about 500 to 550 feet above the Gopalpur-Upper Dhadka-Satpukhuriya seam. But the bore-hole to the Ghusick seam shows that the Raniganj measures, which overlie it, are of the order of 700 to 750 feet thick. In order, therefore, to regard these two seams as equivalent we must suppose that within a very short distance these uppermost Raniganj measures have thickened to the extent of about 200 feet. There is no suggestion of any such increase in thickness as we approach the Kalipahari area, nor is this borne out by the evidence of these upper Raniganj beds in any other part of the field.

(iii) The difference in character between the two coal seams and the associated strata.

The factors that suggest the equivalence of the Satpukhuriya and the Ghusick seams are :—

(i) The similarity in composition of the sections now being worked.

(ii) The occurrence of thick shales above both seams.

Many other factors, however, point to the conclusion that the Ghusick seam occurs at a lower horizon in the upper Raniganj measures than does the Satpukhuriya seam.

As above mentioned, the writer considers the Satpukhuriya seam to be represented by the 9-foot seam of shaly coal of the Asansol bore-hole, and by the 7- or 8-foot seam of inferior quality in the Kumardiha area. Further east, this seam appears to be of no economic importance and when the uppermost Raniganj measures are again met with in the eastern part of the field, it is impossible to say to which of the thin seams, above the Upper Kajora seam, the horizon should be applied.

X.—Hirakhun - Bharat Chak - Narsamuda—4-foot seam to the south-east of Satpukhuriya.

Narsamuda-Bharat Chak seam.

About 300 feet above the Gopalpur seam, and 250 feet below the top of the Raniganj series to the west of Asansol, is the 4 ft. 6 in. Narsamuda seam of Narsamud acolliery. This seam continues west-south-westwards into the Patmohna area where it is represented by the Bharat Chak seam, and, apparently, to the south of the Damodar

river as the Hirakhun and Nituria seams. To the east of Asansol, it appears to be definitely represented by the 4-foot seam of the Satpukhuriya area. The latter coal seam occurs about 340 to 350 feet above the Gopalpur-Satpukhuriya seam, and at about the same position with reference to the top of the Raniganj measures as in the more western parts of the field. It has been worked from inclines in the area west of Kalipahari. In the more eastern parts of the coalfield, north-east of Raniganj, a 3- to 5-foot seam is proved about 250 feet above the Upper Kajora seam near Dakshinkhanda village, but further south-east near Tamla, a 4-foot seam occurring about 140 feet above what is apparently the Upper Kajora-equivalent, is succeeded a short distance above by Panchet beds. If we regard these thin seams as the equivalent of the Narsamuda seam of the west, we must assume a very great decrease in the thickness of these uppermost Raniganj beds above the Ghusick-Upper Kajora seam.

Satpukhuriya-Kalipahari seam.

Eastern end of coalfield.

It is quite possible, however, that these supposed Panchet strata overlap the uppermost Raniganj measures in this eastern area, or that the uppermost beds of the Raniganj series are missing.

The Narsamuda seam and its equivalents appear to be the uppermost seam of economic value within the present known limits of the coalfield.

PART III.—ECONOMIC GEOLOGY.

CHAPTER XVI.

RESERVES OF COAL.

General Observations and Analyses.

Coal has been defined as 'a compact stratified mass of mummified plants (which have in part suffered arrested decay to varying degrees of completeness) free from all save a very low percentage of other matter.'[1] Bituminous coals, to which class at least a number of the coals of the Raniganj field belong,[2] have further been described by Dr. M. Stopes,[3] as consisting 'not of mere "dull" and "bright" bands, but of *four* distinctive and visibly differing portions, forming the mass of an ordinary bituminous coal'. These various portions include:—

Constituents of bituminous coal.

(1) *Fusain.*—The equivalent of 'mother of coal', 'mineral charcoal', etc., of various authors. Occurs as patches or wedges of powdery, readily detachable, somewhat fibrous silky strands, flattened parallel to the bedding-plane.

(2) *Durain.*—The equivalent of 'dull' hard coal of various authors. It occurs as bands of variable thickness usually lenticular in shape and has a close, firm texture, which appears rather granular.

(3) *Clarain.*—
(4) *Vitrain.*— } The 'bright' coal of many authors. These constituents occur as narrow bands, often lenticular in shape, and exhibit a hard, glassy appearance. The fracture of vitrain is conchoidal. Unlike durain, they exhibit marked caking properties.

Vitrain and clarain apparently constitute the purest ingredients of the coal seam. The vitrains of Indian coals have recently been studied by Dr. Fermor,[4] from whose paper the following analyses, referring to the Raniganj field, have been taken.

Analyses of vitrain.

[1] Dr. M. C. Stopes and R. V. Wheeler. 'Monograph on the Constitution of Coal', Department of Scientific and Industrial Research, London (1918).

[2] Randall has suggested that many of the non-coking Gondwana coals of India are of a sub-bituminous character. *Rec. Geol. Surv. Ind.*, LVI, p. 229, (1924).

[3] *Proc. Roy. Soc. Lond.*, Series B., Vol. XC, p. 471, (1919).

[4] *Rec. Geol. Surv. Ind.*, LXII, p. 196, (1929).

Vitrains of Barakar age.

—	*Damagaria.* (Damagaria colliery).		*Laikdih.* (Ramnagar colliery).	*Ramnagar.* (Ramnagar colliery).	*Begunia.* (Begunia colliery).
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Moisture	0·61	1·45	1·31	1·56	1·75
Volatile matter	30·51	31·49	31·90	31·00	35·69
Fixed carbon	65·62	63·94	65·32	62·19	59·34
Ash	3·26	3·12	1·47	4·25	3·22
Specific gravity	1·287	1·286	1·283	1·302	1·294

Vitrains of Raniganj age.

—	*Poniati.* (Ningah colliery).	*Dishergarh.* (Lachipur colliery).	*Samla.* (Baidyanathpur colliery).		*Ghusick.* (Kalipahari colliery).	
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Moisture	3·38	2·21	9·61	12·88	5·26	6·24
Volatile matter	38·28	42·17	38·20	34·54	38·83	38·18
Fixed carbon	54·56	51·16	51·79	52·08	52·64	53·80
Ash	3·78	4·46	0·40	0·50	3·27	1·78
Specific gravity	1·307	1·299	1·295	1·314	1·300	1·289

In the above determinations the following characters are exemplified :—

(*a*) That there is a very considerable difference in composition between the vitrains of the Barakar and of the Raniganj measures ; the former including a decidedly lower percentage of moisture and volatile matter, and a correspondingly larger percentage of fixed carbon.

(*b*) In the case of the individual coal seams of the Barakar measures, a similar, though gradual increase in the percentage of moisture and volatile matter as we ascend the sequence is indicated, though no such variation is suggested in the instance of the seams of the Raniganj series.

It is not surprising, therefore, to find that these characters are exemplified within the coal as a whole, (*see* Tables of analyses, pp. 272-277) though in a less forcible manner.

The coal seams of the Raniganj field, in fact, fall into two fairly well-marked groups, which correspond with the major geological classification of the measures into a lower (Barakar) and an upper (Raniganj) series. The characteristics of these two groups are as follows :—

Analytical classification of coal seams.

I. *Barakar coals.*

(*a*) A relatively low percentage of moisture ranging in most instances from 1 to 3·50 per cent.

(*b*) A comparatively low percentage of volatiles, ranging in most cases from 21 to 30 per cent.

(*c*) A high proportion of fixed carbon ranging from about 52 to 64 per cent ; a figure around 55 per cent. is often recorded.

(*d*) The better quality coals are excellent steam-coals and exhibit marked tendencies to form a hard metallurgical coke.

II. *Raniganj coals.*

(*a*) A relatively high proportion of moisture, ranging from about 3 to 10 per cent., though in the case of the Dishergarh seam from 1·35 to 3 per cent. is often recorded.

(*b*) In the case of the better quality seams, the percentage of volatiles is high, normally ranging from 29 to as much as 38 per cent.

(*c*) With the exception of the Dishergarh and Sanctoria seams of the basal measures of the western part of the field, the coals either fail to cake at all or produce a very soft, porous coke. Most of the better quality coals are excellent gas-coals, and free-burning steam-coals.

The above-mentioned characters have apparently been borne in mind in arriving at the classification that has been adopted by the Indian Coal Grading Board. In this classification the seams of the Barakar measures are, as a whole, grouped under the heading of 'Low Volatile Coal', whilst those of the Raniganj measures are described as 'High Volatile Coal'. The further classification into the various grades is as follows :—

Classification adopted by the Grading Board.

	Low Volatile coal. (Barakar series).	*High Volatile coal.* (Raniganj series).
Selected.	—Up to, but not exceeding 13 per cent. ash, and over 7,000 calories.	Up to, but not exceeding 11 per cent. ash ; over 6,800 calories ; under 6 per cent. moisture.
Grade I.	—Up to, but not exceeding 15 per cent. ash, and over 6,500 calories.	Up to, but not exceeding 13 per cent. ash ; over 6,300 calories ; under 9 per cent. moisture.
Grade II.	—Up to, but not exceeding 18 per cent. ash, and over 6,000 calories.	Up to, but not exceeding 16 per cent. ash ; over 6,000 calories ; under 10 per cent. moisture.
Grade III.	—Coals inferior to the above.	Coals inferior to the above.

Constituents.

Regarding the various constituents of coal, the following observations may be made:—

Ash.

The ash of a coal seam represents the inorganic contents of the coal and (as has been mentioned by previous writers including Dr. Fox,[1]) comprises:—

Derivation of ash.

Primary.—
- (*a*) Inorganic substance in the original plants.
- (*b*) Clayey particles laid down with the vegetable debris.

Secondary.—
- (*c*) Carbonate and sulphide deposited by water percolating along the joints of the coal.
- (*d*) Matter introduced by igneous action. (see paper by Dr. Fox entitled 'Low Phosphorus coking coal in Giridih coalfield[2]').

In the case of many of the coals of the Raniganj field, the lateral variation exhibited by a number of the seams is probably attributable, in the main, to variations in the amounts of extraneous clayey material, which have been deposited with the vegetable debris during the process of sedimentation, rather than to any marked differences in the types of vegetation laid down. Not only is the ash injurious to the quality of the seam in that it replaces an equal volume of heat-producing coal, and owing to its relatively high specific gravity adds appreciably to the weight of the fuel, but also, in actual practice, in the case of a coal in which the ash exhibits a decided tendency to clinker, a proportion of unburnt carbon is usually included within the residual ash, thus preventing complete combustion from taking place.

Injurious effects.

Moisture.

The moisture content of a coal, apart from hygroscopic moisture, appears to be in colloidal association with the coaly substances. In consequence of this, coals of high moisture content have a higher specific gravity than similar coals of low moisture content. Dr. Fox has indicated,[3] that high proportions of moisture decrease the caking properties of coal in a greater degree than do large percentages of ash. None of those coals of the Raniganj field that include a relatively large percentage of moisture have

Effect on caking.

[1] *Mem. Geol. Surv. Ind.*, LVI, p. 179, (1930).
[2] *Rec. Geol. Surv. Ind.*, LIX, pp. 371-404, (1926).
[3] *Mem. Geol. Surv. Ind.*, LVI, p. 181, (1930).

been found to yield a hard metallurgical coke. The moisture content also lowers the calorific value of a coal, by absorbing a certain proportion of the total heat evolved for its own evaporation and in the form of latent heat.

Volatile matter.

Effect on thermal efficiency.

Past researches on the combustion of coal have shown that coals containing about 20 per cent. of volatile matter yield the greatest thermal efficiency, and that the greater the proportion of oxygen included in these volatiles, the lower the calorific value. Oxygenation can apparently take place during the process of weathering of the coal. Such a process at least partially explains the deterioration of coal in the vicinity of the outcrop and when left exposed on the surface for any considerable period.

Spontaneous combustion.

The tendency to ignite by spontaneous combustion, greater in certain Raniganj coals than in others, was commented on by Dr. Blanford.[1] This character has been exemplified in a number of instances in the Raniganj field, both in the early days of mining and in recent years. Such cases of spontaneous combustion have resulted not only through the crushing of pillars of coal within the mine, but during the transportation of large quantities of coal over long distances by sea, and in the case of slack coal when piled for any length of time in heaps of a greater height than about six feet.

Tendency to disintegrate.

Another detrimental character of certain Raniganj coals is the tendency to disintegrate rapidly when stacked for long periods, or during transportation. In this respect the coals of the Raniganj measures are, perhaps, the worst offenders.

Utilisation.

The purposes for which the various grades of coal of the Raniganj field are utilised, include :—

1. Steam-raising.
2. Manufacture of coal-gas.
3. Manufacture of metallurgical coke.
4. Manufacture of soft coke.
5. Powdered fuel.

[1] *Op. cit.*, p. 175.

1. *Steam-raising.*

By far the greater proportion of the output of coal of the Raniganj field is used for this purpose. The high grade Barakar coals, as is the case with those of the Jharia field, are short-flamed coals and therefore give better results when used in an ordinary locomotive boiler or in any other type of boiler with a forced draught, than do the high volatile coals of the Raniganj stage. This phenomenon has been pointed out by Dr. Coggin Brown in an interesting paper entitled 'Indian Coal Problems'[1]. He states :—

Effect of mixing.

'But for some purposes a mixture of Dishergarh, Poniati and Jharia coals will give results superior to those from either of them in isolation and comparable to those from Welsh coals'.

Correspondingly superior results might be expected by mixing Dishergarh and Poniati coal with the low volatile product of, say, the Damagaria seam; whilst it is probable that the efficiency of the high volatile coals, as a whole, would be improved by blending on similar lines.

2. *Manufacture of coal-gas.*

The better quality coals of the Raniganj measures have long proved their excellence in the manufacture of coal-gas. Of these, the coal of the Dishergarh and Poniati seams is largely used, and yields, as a bye-product, a porous coke of good quality.

3. *Manufacture of metallurgical coke.*

Very considerable literature and lengthy discussions have, in recent years, centred around the problem of the metallurgical caking coals of India, and a number of experiments in the use of various seams of the Raniganj field have been forthcoming.

Early experiment.

In 1874, in commenting on a number of tests made with coals from Dumarkanda, Sanctoria, Banali, Raniganj and Mangalpur, Mr. Hughes wrote as follows 'Only one of these five selected coals, that of Sanktoria (Sanctoria) is truly coking.' In more recent years, the Ramnagar seam and the upper and lowest portions of the Laikdih seam of Victoria colliery, have proved to give a satisfactory metallurgical coke, which has been utilised in the Kulti furnaces. In addition, the Dishergarh seam of the western part of the field, on mixing with suitable proportions of low volatile Jharia coal, has been used

[1] *Bull. of Indian Industries and Labour*, No. 36, p. 28, (Dec. 1926).

in considerable quantity in the production of blast-furnace coke. Further tests, carried out at the instigation of Dr. Fox,[1] have confirmed the belief that, with similar blending, the Begunia seam also yields a hard serviceable coke, and these tests have further indicated the possibility of the use of the low volatile Damagaria seam (at least the lower portion, which is of better quality) when mixed in suitable proportions with Dishergarh coal. Up to the present time, the higher coal seams of the Raniganj measures and also the lower seams of the eastern part of the coalfield, have been proved to yield only a relatively soft coke, unsatisfactory for use in present-day furnaces. In the above-mentioned experiments, a much harder coke was obtained by heating to 1100° C. than at the carbonising temperature of 850° C.

Recent tests.

The following analyses illustrate the composition of certain of the coals of the Raniganj field, which have so far proved suitable for the production of metallurgical coke :—

Analyses of coal and ash.

—	(a)	(b)
	Per cent.	Per cent.
Moisture	2·0	2·25
Volatile matter	27·4	34·11
Sulphur	..	0·39
Fixed carbon	55·20	53·64
Ash—Total	15·40	10·00
Ash details—		
Silica	8·285	5·050
Alumina	3·953	2·400
Ferric oxide	1·760	1·000
Manganese oxide	0·057	?
Lime	0·508	1·000
Magnesia	0·215	0·250
Sulphur trioxide	?	?
Phosphorus pentoxide	0·252	0·314
Other constituents	0·367	?
Phosphorus in coal	0·105	0·13

(*a*) Ramnagar colliery, Ramnagar seam. This coal provided coke to the Bengal Iron Co., at Kulti. (A. Dawes Robinson).

(*b*) Saltor colliery, Dishergarh seam. (Ash averaged by two analyses of Dishergarh seam). *Rec. Geol. Surv. Ind.*, LXI, pp. 294-317, (1928).

[1] *Rec. Geol. Surv. Ind.*, LXI, p. 311, (1928).

Gillanders Arbuthnot & Co.'s Begunia colliery.

Begunia seam.

(Ultimate analysis on dried sample; carried out at the Government Test House, Alipore, Calcutta).

	Per cent.
Carbon	70·90
Hydrogen . . .	4·83
Nitrogen . . .	2·08
Sulphur . .	0·58
Ash . . .	13·75
Oxygen (by difference) . .	7·86
Total .	100·00

Analysis of ash.

Silica	55·55
Iron oxide	9·00
Alumina	26·56
Lime	3·50
Magnesia . . .	1·63
Alkalies	trace
Sulphuric anhydride . .	3·43
Phosphoric anhydrids . .	0·44
Total .	100·11

Sample of coke made by the Bengal Iron Co., Kulti, from coal obtained from the Laikdih seam, Victoria colliery.

(Analysis carried out at the Government Test House, Alipore, Calcutta.)

	Per cent.
Moisture	0·40
Sample dried—	
Ash	18·00
Volatile	0·40
Sulphur	0·78
Fixed carbon (by difference)	80·82
Total	100·00

Analysis of ash.

Silica	44·00
Iron oxide	30·28
Alumina	21·72
Lime	1·60
Magnesia	1·62
Sulphur (as sulphate) . .	0·09
Phosphoric acid . . .	0·46
Total .	99·77

Froth flotation experiments.

A number of tests have been carried out by Mr. W. Randall,[1] on the cleaning of Indian coals by the Froth Flotation process. Using the caking coals of the Laikdih and Ramnagar seams, an appreciable decrease in the percentage of ash was effected. In the case of the weakly caking and non-caking coals Mr. Randall observed:—

'Coking coals are those of which the better constituents are strongly coking, and the inferior constituents are weakly coking or non-coking. In the first class coking coals, the proportions of the constituents are such that the coal gives a satisfactory coke. In the second class coking coals, the proportions of the constituents are such that the coal gives a weak coke of high ash content. Some of the more inferior coking coals are of such quality that they may be regarded as commercially non-coking. The difference is merely one of a difference in the proportion of the constituents. Flotation can concentrate the better constituents, vitrain and clarain, and eliminate the higher-ash non-coking ones, durain and fusain.

[1] *Rec. Geol. Surv. Ind.*, LVI, p. 229, (1924).

Hence the proportion of clean product, of a quality suitable for coking, which can be separated, depends only on the quality of the seam and its heterogeneous nature, *i.e.*, its cleanability. Flotation clean products from second class coking coals have given cokes of excellent quality, and one of the largest iron and steel works in India has expressed the opinion that they are as good as can be desired.'

'Flotation, or any other process, cannot separate a coking product from a coal which does not contain any coking constituents. India has large reserves of sub-bituminous non-coking coals. Their high moisture contents are an indication of the fact that they are constituted of vegetable products much less altered than is the case in the coking coals. The constituents of these sub-bituminous coa's are all non-coking, and for this reason the coals are incapable of being cleaned to yield coking products.'

4. *Manufacture of soft coke.*

Attention has already been drawn by Dr. Fox,[1] to the relatively extensive manufacture of soft coke (*poora-koela*) within the Raniganj and Jharia fields. This industry is practised mainly by the smaller colliery proprietors working seams of inferior coal which, in the present state of the market, is regarded as unfit for steam-raising and other purposes in the natural state. When converted into coke, or semi-coke, however, the product finds a ready sale, largely for home consumption. The lump coal is stacked in large heaps varying up to as much as 20 tons, and is ignited from a hole at the top of the heap. The heaps are then covered with a layer of slack and dust coal and combustion is allowed to proceed gradually for about 3 to 4 days until the whole of the coal is affected in a greater or less degree. A certain proportion of charred coal, and more or less completely burnt coal, invariably results from this wasteful method, though if properly regulated, a coke or semi-coke of fairly even quality—resembling the product obtained by low temperature carbonisation—is obtained, representing from 60 to 70 per cent of the total weight of coal used.

Usual method of manufacture.

Dr. Coggin Brown also associates himself with this question in the paper to which reference has already been made.[2] He states :—

'The first attempts to manufacture soft coke on a large scale under scientific conditions in India appear to have been made by Dr. Edgar Evans at Kustore colliery in 1920. It is claimed that several tons of first class soft coke were made in this retort from non-coking coal of the Toposi type, and that this material found ready sale.'

Experiments on a scientific scale.

[1] *Capital*, July 5th 1928, p. 2; and July 12th 1928, p. 58.
[2] *Bull. of Indian Industries & Labour*, No. 36, (Dec. 1926).

The analyses of the Toposi coals used, and the soft coke produced in the Kustore experiment are given as follows :—

	Lump coal.	Small coal.	Soft coke (dried sample).
	Per cent.	Per cent.	Per cent.
Moisture .	3·10	2·94	..
Volatile matter	37·17	36·39	4·58
Fixed carbon	46·85	46·41	65·57
Ash . .	12·87	14·26	29·85

The following analyses of typical Indian soft cokes as they appear on the market, are also given by the above-mentioned author (Dr. Coggin Brown).

Analyses of 'poora koela', Raniganj field, 1919.

No.	Description.	Volatile matter.	Moisture.	Ash.	Fixed carbon.
		Per cent.	Per cent.	Per cent.	Per cent.
1	Toposi	8·50	dried	26·8	65·7
2	Do.	7·12	3·75	29·04	63·83
3	Do.	5·30	2·89	50·92	43·78
4	Do.	4·13	5·00	42·56	53·31
5	Kalipahari	7·21	5·37	28·42	64·37
6	Do.	5·61	5·50	37·60	56·79
7	Do.	5·18	dried	37·58	57·24
8	Do.	5·78	5·52	38·00	56·22
9	Jote Janaki . .	6·03	dried	35·12	58·85
10	Do. . . .	6·80	dried	30·00	63·20
11	Do. . . .	6·00	6·10	29·00	65·00
12	Do. . . .	5·34	6·70	23·52	71·14
13	Toposi	6·18	8·00	19·90	73·92
14	Do.	5·59	8·10	32·20	62·21
15	Do.	4·73	8·10	37·38	57·89
16	Do.	8·11	10·40	31·32	60·07

Average sulphur content of the above samples :—

Nos.	1 to 4.	Toposi	0·20
,,	5 to 8.	Kalipahari	0·25
,,	9 to 12.	Jote Janaki	0·28
,,	13 to 16.	Toposi	0·26

(All the above samples were taken from 'poora koela' heaps, made by the native process.)

There is little doubt that a large scope exists for the expansion of this industry on more economic and scientific lines. Could the process be extended to the conversion of the slack of the better

quality coals that, by the nature of their liability to disintegrate unavoidably forms a very appreciable percentage of the coal extracted, a useful and valuable product would be obtained.

5. *Powdered Fuel.*

As pulverised fuel, the slack of certain Raniganj coals is being used at the rate of 1,000 tons per month, by the Indian Copper Corporation at Mosaboni, Singhbhum. These coals, regarding which details have very kindly been supplied by Mr. Robson, Works Superintendent, include the Noga seam of Chapui colliery and the Noga or the Siarsol seam of Siarsol colliery. On account of their high volatile content, which gives easy ignition; the refractory ash, which prevents clinkering; and the low sulphur content, these coals have proved advantageous to the processes of refinement of the copper. Other seams of equally suitable character doubtless exist among the high-volatile types of the Raniganj series.

Again, in several of the rotary kilns of the cement works of India, the slack coal from the Dishergarh and Poniati seams is being used successfully.

ANALYSES OF RANIGANJ COALS.

Analyses of Raniganj coals have been carried out by a number of investigators. Among these, the figures published by Mr. Tween,[1] as a result of experiments made during the years 1870-1873, were undoubtedly useful in the early days of mining within the field. In addition to approximate analyses, he also determined the percentages of the principal elements within the coal-substance and the ash, though unfortunately no calorific values are given. He, however, included a list of the specific gravities of the various seams, which vary from 1·343 in the case of the better quality (Sanctoria) coal, to nearly 1·5 in the case of the very inferior types.

Tween, 1870-1873.

In 1898, Professor W. R. Dunstan, published a series of detailed analyses of Bengal coals.[2] In his earlier tables the moisture of the coal was included with the percentage of volatile matter. This error, serious in the case of many of the high-moisture coals of the Rani-

Dunstan, 1898 and 1905.

[1] *Rec. Geol. Surv. Ind.*, X, pp. 156-157, (1877).

[2] *Indian Agricultural Ledger*, No. 14, (1898); and 'The coal Reserves of India and their Development' by Professor Dunstan, Technical Reports and Scientific Papers, Imperial Institute, (1903).

ganj measures, was, however, rectified when a second series of analyses was published in 1905.[1] Calorific values were included in these determinations, though specific gravities were unfortunately not given.

Saise, 1904.

In 1904, a number of assays of the coals, worked in the Raniganj field, were published by Dr. W. Saise.[2] In this instance, however, calorific values were again not included. Later, in 1910, Lieutenant-Colonel F. E. Cunninghame Hughes [3] made a number of determinations on the composition and calorific value of various coals of Bengal and Bihar & Orissa. Each of the samples analysed was apparently taken from a few lumps only, from 5 to 50 lbs. in total weight, so that they can scarcely be regarded as representative of the seam as a whole or of large sections. The results of both these latter investigators showed, however, that the coals of the Barakars differed consistently from those of the Raniganj measures in containing less moisture and generally, also, in having a smaller percentage of volatile hydrocarbons.

Cunninghame Hughes, 1910.

Indian Coal Grading Board.

The establishment, within recent years, of the Indian Coal Grading Board has, however, done much towards solving the problem of the quality and classification of Indian coals. Uniform methods of sampling and of analysis have been adopted and, as a result, a series of approximate determinations, which can safely undergo comparison, are now available. In so far as the Raniganj field is concerned, these analyses, carried out at the Government Test House, Alipore, Calcutta, during the years 1925 to 1929, are included in the tables that follow (Tables 7 and 8).

Method of analysis.

The method of quoting the analyses of the various coal samples is as follows. The moisture content is stated, but the percentage of ash, volatile matter, and fixed carbon, are calculated so as to total 100, exclusive of moisture. Unfortunately, the specific gravity is never given, and the nature and colour of the ash only occasionally. The calorific value is quoted in terms of calories and is, apparently, calculated on a 'dried' sample; so that, in the case of the high-moisture

[1] *Flying Seal Series*, No. 364, Imperial Institute, London, 28th July, 1905.
[2] *Rec. Geol. Surv. Ind.*, XXXI, p. 104, (1904).
[3] *Trans. Min. Geol. Inst. Ind.*, V, p. 114, (1910).

coals of the Raniganj measures, the figures given are, doubtless, appreciably in excess of the actual thermal efficiences of the coals. Regarding this method of computation, the Coal Grading Board publish the following note.[1]

'About 5 grams of the powdered sample is dried separately in an Air Oven at 110° C. to constant weight. About 1 gram of the oven-dried material is put in the screw press and compressed into a pellet. This pellet is then weighed and the calorific value is determined immediately afterwards by tests in a Mahler-Cook Bomb Calorimeter.'

[1] Publication of the Indian Coal Grading Board, p. 6, (1928), containing a list of Graded Coals, Copies of the Act and Rules, and other information.

TABLE 7.—*Coal analyses—Barakar measures.*

Name of seam.	No. of analysis.	Name of colliery.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Calorific value. (Calories.)	REMARKS.
			Per cent.	Per cent.	Per cent.	Per cent.		
Badjna . . .	1	Badjna. (A. Yule & Co.) . .	1·10	21·00	64·40	14·60	6,637	
Mahatadih . . .	2	Mahatadih. (Guzdar & Co.) .	1·00	19·90	51·80	28·30	5,916	
Damagaria—Salanpur 'A' .	3	Damagaria. (Turnbull Bros.) .	1·24	23·00	62·00	15·00	7,149	
	4	Bhagrand. (Bengal Coal Syndicate).	0·85	21·55	62·05	16·40	7,160	
	5	Garh Dhemo. (Garh Dhemo Coal Co.)	1·84	18·80	62·20	19·00	6,904	8 ft. section.
Rangamati—Salanpur 'C' Churulia—Kasta .	6	Rangamati. (Ambler & Co.) .	1·27	21·10	55·45	23·45	6,310	
	7	Hariajam. (Ambler & Co.) .	1·16	24·00	53·85	22·15	6,312	12 ft. seam. (? Rangamati seam).
	8	Central Salanpur. (Bengal Coal Syndicate.)	0·97	25·45	52·65	21·90	6,537	
	9	Churulia. (F. W. Heilgers & Co.)	3·30	28·40	55·10	16·50	6,720	Bottom 6 to 7 ft.
	10	Poriarpur. (Martin & Co.) .	2·66	32·05	57·00	10·95	7,318	Bottom 12 ft.
	11	Kasta. (H. V. Low & Co.). .	2·10	30·90	56·90	12·20	7,049	Bottom 12 ft.
	12	Ditto .	2·30	29·90	51·60	18·50	6,620	Middle 10 ft. above 8 ft. bottom section.
	13	Sultanpur. (H. V. Low & Co.) .	2·70	28·80	56·50	14·70	6,800	Bottom 12 ft.
	14	Ditto .	4·60	30·10	57·30	12·60	7,357	Bottom 8 ft.
	15	Ditto .	2·30	29·00	53·60	17·40	6,733	Middle 15 ft.
	16	Jorkuri. (Agabeg Bros.) . .	3·10	30·90	55·70	13·40	7,015	Bottom 18 ft.
	17	Korrabad. (Martin & Co.) .	2·32	30·80	52·20	17·00	6,771	
	18	Ditto .	2·60	29·00	51·90	19·10	6,372	Bottom 15 ft.
	19	Arang. (H. V. Low & Co.) .	3·80	23·80	52·75	18·45	6,521	Bottom 8 ft.
Bahira '4' . . .	20	Bahira (Borrea). (Balmer Lawrie & Co.)	1·50	26·90	53·10	15·00	7,127	
Shampur '5'—Laikdih—Bahira '1 to 3' .	21	Shampur. (Geo. Henderson & Co.)	1·02	27·00	51·85	21·15	6,576	
	22	Ramnagar. (Martin & Co.) .	2·90	27·00	59·70	13·80	7,271	
	23	Victoria. (Balmer Lawrie & Co.)	1·52	27·35	60·90	11·25	7,337	Top seam.
	24	Ditto .	1·70	27·38	56·00	16·62	6,857	
	25	Ditto .	1·20	25·40	59·00	15·60	7,170	Middle seam.
	26	Ditto .	1·30	22·40	62·00	15·60	7,223	Top 10 ft. } Bottom
	27	Ditto .	1·40	26·00	62·60	11·40	7,632	Bottom 17 ft. } seam.
	28	Bahira (Borrea). (Balmer Lawrie & Co.)	2·00	25·30	57·60	17·10	6,737	Bahira '3' seam.
Ramnagar . . .	29	Ramnagar. (Martin & Co.) .	(see analysis by A. Dawes Robinson, p. 265).					
Chanch—Begunia . .	30	Chanch. (A. Yule & Co.) . .	1·31	25·75	61·30	12·95	7,186	
	31	Begunia Khas. (Gillanders Arbuthnot & Co.)	2·10	27·60	60·00	12·40	7,194	
	32	Bahira (Borrea). (Balmer Lawrie & Co.)	3·33	27·50	63·35	9·15	7,347	Bahira top seam.

TABLE 8.—*Coal analyses—Raniganj measures.*

Name of seam.	No. of analysis.	Name of colliery.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Calorific value. (Calories.)	REMARKS.
			Per cent.	Per cent.	Per cent.	Per cent.		
Taltor	33	Nandi Sibpur. (Kar & Co.) .	6·30	29·60	55·00	15·40	6,714	4 ft. 6 in. seam.
	34	East Nandi. (East Nandi Coal Co.)	6·60	30·90	56·00	13·10	6,672	
Sanctoria—Poniati . . .	35	Seetalpur. (A. Yule & Co.) .	2·81	32·00	59·00	9·00	7,469	10 ft. 4 in. section.
	36	Chinchuria. (Balmer Lawrie & Co.)	2·90	32·80	57·00	10·20	7,219	Lower 10 ft. to 10 ft. 6 in. section.
	37	Jayramdanga. (Balmer Lawrie & Co.)	5·29	27·36	62·64	10·00	7,218	18 ft. seam.
	38	West Baraboni. (J. N. Dass & Co.)	4·07	36·70	54·10	9·20	7,396	
	39	Baraboni. (N. C. Sircar & Co.) .	2·82	28·80	62·80	8·40	7,453	
	40	New Baraboni. (W. C. Bannerji & Co.)	3·70	33·80	56·60	9·60	7,168	Bottom 14 to 16 ft.
	41	South Baraboni. (Banerji & Co.)	5·10	33·80	55·80	10·40	7,130	
	42	S. E. Baraboni. (Gillanders Arbuthnot & Co.)	2·71	28·60	62·20	9·20	7,201	
	43	Charanpur. (Bird & Co.) . .	5·03	32·61	55·50	11·89	6,925	
	44	Faridpur. (W. C. Bannerji & Co.)	3·34	28·00	62·60	9·40	7,074	
	45	Banksimila. (A. Yule & Co.) .	3·66	31·95	59·05	9·00	7,106	
	46	West Jamuria. (Macneill & Co.).	4·50	32·20	57·70	10·10	7,068	
	47	Shripur. (Turner Morrison & Co.)	3·13	31·06	59·10	9·84	7,389	
	48	Ningah. (Turner, Morrison & Co.)	2·98	35·43	54·68	9·89	7,382	
	49	Jamuria. (Macneill & Co.) .	4·97	35·08	55·07	9·85	7,305	Pits 7 and 8.
	50	Pretoria. (A. Yule & Co.) . .	3·94	32·90	55·60	11·50	6,998	
	51	Sibpur. (A. Yule & Co.) . .	3·40	33·05	55·60	11·35	6,861	16 ft. thick.
	52	Viceroy. (A. Yule & Co.) . .	6·00	30·70	59·90	9·40	7,091	No. 1 Pit. No. 12 working place.
	53	Nandi—Sibpur. (Kar & Co.) .	4·80	33·70	55·00	11·30	6,970	
	54	Nandi. (A. Yule & Co.) . .	4·91	24·20	54·10	11·70	6,846	
	55	Ditto . .	6·00	31·50	56·70	11·80	6,832	
	56	Adjai Valley. (A. Yule & Co.) .	6·30	33·00	56·20	10·80	7,078	
	57	Ditto .	8·80	30·00	59·10	10·90	6,893	
	58	Damodarpur. (A. Yule & Co.) .	4·85	32·83	55·80	11·35	7,033	
	59	Akholpur. (Macneill & Co.) .	7·70	31·20	57·65	10·95	7,028	Pit No. 2.
	60	Ditto .	5·67	33·08	55·70	11·22	7,061	Pit No. 3.
	61	Mandalpur. (Macneill & Co.) .	5·10	31·30	57·50	10·90	7,047	Pit No. 1.
	62	Ditto .	5·90	29·50	61·70	8·80	7,346	Pit No. 3, 4 ft. 3 in.

TABLE 8.—*Coal analyses—Raniganj measures*—contd.

Name of seam.	No. of analysis.	Name of colliery.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Calorific value. (Calories.)	REMARKS.
			Per cent.	Per cent.	Per cent.	Per cent.		
Dahuka (? = Poniati) .	63	Dahuka. (N. C. Sircar) . .	7·40	31·50	53·90	14·60	6,458	
Hatinal—Koiti . . .	64	Sanctoria. (A. Yule & Co.) .	2·15	31·05	48·90	20·05	6,346	
	65	Bhaskajori. (Bird & Co.) . .	3·60	21·90	63·60	14·50	6,827	
	66	Jayramdanga. (Balmer Lawrie & Co.)	3·70	31·90	52·40	15·70	6,728	
	67	Ditto .	4·20	33·95	50·30	15·75	6,764	
	68	Ditto .	4·20	33·40	52·90	13·70	6,793	Bottom 8 ft.
	69	Southeast Baraboni. (Gillanders Arbuthnot & Co.)	2·94	35·18	52·64	12·18	7,076	
	70	Ditto .	3·60	33·10	54·80	12·10	7,111	
	71	Charanpur. (Bird & Co.) . .	4·30	32·40	53·10	14·50	6,769	Bottom 8 ft.
	72	Charanpur. (Apcar & Co.) .	6·60	34·30	52·40	13·30	6,836	
	73	Faridpur. (W. C. Banerji & Co.)	3·23	27·60	57·80	14·60	6,759	
	74	Banksimila. (A. Yule & Co.) .	4·70	33·20	53·70	13·10	6,939	Bottom 8 ft.
	75	Pretoria. (A. Yule & Co.) . .	5·10	30·90	52·60	16·50	6,525	11 ft. section.
	76	Sibpur. (A. Yule & Co.) . .	5·90	30·55	55·66	13·80	6,828	12 ft. section.
Chichuria (? = Koiti) .	77	Bamanband. (N. C. Sircar) .	6·60	29·70	51·40	18·90	6,251	6 ft. to 7 ft. 6 in. section.
	78	Chinchuria. (N. C. Sircar) .	6·10	30·00	53·90	16·10	6,753	8 ft. section.
Dishergarh . .	79	Puapur. (Powapur Coal Co.) .	3·95	30·75	49·45	19·80	6,419	
	80	Puapur (Powapur). (Jadavlall & Sons.)	2·70	32·40	58·15	9·45	7,413	
	81	Nadiha. (Macneill & Co.) . .	3·20	28·90	53·70	17·40	6,525	
	82	Chowrassi. (Macneill & Co.) .	3·88	33·41	51·15	15·44	6,849	No. 4 Incline.
	83	Ditto .	3·30	33·50	53·25	13·25	7,090	No. 5 Incline.
	84	Ditto .	2·60	32·00	57·40	10·60	7,282	Top 10 ft.; 2 ft. left in floor.
	85	Ditto .	3·16	31·15	48·50	20·85	6,303	No. 6 Incline.
	86	Ditto .	2·41	34·25	52·92	12·83	7,010	No. 2 Incline.
	87	Deliya (Deoli). (A. Yule & Co.) .	2·57	33·95	54·95	11·10	7,288	
	88	Saltor. (Bird & Co.) . .	2·52	37·75	51·55	10·70	7,273	
	89	Parbelia. (A. Yule & Co.) . .	1·35	32·75	56·00	11·25	7,300	
	90	Sanctoria. (A. Yule & Co.) .	2·00	36·85	51·55	11·60	7,139	15 ft. 4 in. section.
	91	Dishergarh. (Macneill & Co.) .	2·64	31·30	59·88	8·82	7,296	
	92	Seetalpur. (A. Yule & Co.) .	1·98	31·90	56·20	11·90	7,288	12 ft. section.
	93	Sodepur. Pits 9 and 10. (A Yule & Co.) .	2·30	33·60	54·20	12·20	7,061	About 17 ft. thick; 2 ft. left in roof.
	94	Chhota Dhemo (A. Yule & Co.) .	2·50	33·00	53·00	14·00	6,966	
	95	Bejdihi. (Macneill & Co.) . .	2·70	33·30	57·20	9·50	7,490	14 to 15 ft.

Disbergarh—*contd.*	96	Aldihi. (Macneill & Co.)	2·41	29·20	61·00	9·80	7,436	
	97	Methani. (Macneill & Co.)	2·55	34·05	54·65	11·30	7,169	
	98	Luchhipur. (Balmer Lawrie & Co.)	2·20	32·20	56·80	11·00	7,362	
	99	Luchhipur. (Bird & Co.)	3·13	31·30	58·98	9·72	7,362	
	100	Dhemo Main. (Macneill & Co.)	2·95	28·74	60·82	10·44	7,316	
	101	Barmundia. (Balmer Lawrie & Co.)	1·48	30·60	58·60	10·80	7,504	
	102	Sudi. (Morarji Mubraji & Co.)	4·10	32·70	55·20	12·10	7,154	
	103	Bara Dhemo. (A. Yule & Co.)	2·25	32·80	55·70	11·50	7,194	8 ft. 4 in. section.
	104	Kunlapur. (Asansol Coal Co.)	3·54	31·13	52·77	16·10	6,909	
	105	Kunlapur. (K. M. Sircar)	2·66	31·89	53·80	14·31	6,803	
	106	Manoharbahal. (N. C. Sircar)	4·14	32·30	55·25	12·45	7,061	
	107	Ditto	3·70	32·90	54·60	12·50	6,907	7 ft. 6 in. section.
Chowkidanga—Jote Janaki	108	Toposi. (Kilburn & Co.)	6·10	31·25	54·00	14·75	6,744	
	109	Jote Janaki. (Banerji Santan)	7·48	32·88	50·12	17·00	6,466	
Samla (? = Jote Janaki)	110	Samla—Ramangar. (Martin & Co.)	11·00	31·50	57·10	11·40	6,803	Bottom 8 ft. 6 in.
	111	Samla. (Martin & Co.)	7·75	32·15	55·90	11·95	6,839	
	112	Samla—Gobindpur. (Martin & Co.)	9·80	32·40	55·10	12·50	6,800	
	113	Kendra. (Martin & Co.)	7·87	33·30	54·35	12·35	6,787	
	114	Kendra. (K. Agarwalla)	9·79	31·12	54·98	13·90	6,839	
	115	Darula. (Balmer Lawrie & Co.)	7·73	34·03	52·62	13·35	6,696	
	116	South Samla. (Villiers & Co.)	12·86	33·00	54·40	12·60	6,765	
Raghunathbati	117	Damuda. (Balmer Lawrie & Co.)	3·90	31·00	57·90	11·10	7,037	
Manoharbahal—Rana—Porlarpur—Satgram—Toposi—Kenda—Chora.	118	Manoharbahal. (N. C. Sircar)	5·24	30·76	50·80	13·45	6,458	8 ft. 9 in. No. I Incline.
	119	Ditto	5·75	33·95	53·75	12·30	7,088	
	120	Ditto	4·97	33·20	52·80	14·00	6,671	No. 2 Incline.
	121	Bara Pukhuriya. (Balmer Lawrie & Co.).	4·30	31·70	55·20	13·10	6,779	
	122	Rana. (N. C. Sircar)	5·40	31·00	55·00	14·00	6,602	
	123	Kankhaya. (A. Yule & Co.)	5·82	32·50	55·00	12·50	6,842	
	124	Bogra. (H. B. Dass)	4·35	33·50	54·30	12·20	7,076	
	125	Banali. (H. V. Low & Co.)	6·16	34·05	46·67	19·28	6,368	
	126	Banali. (N. C. Sircar)	5·50	31·50	55·70	12·80	6,313	9 ft. section.
	127	Khas Sathgram. (L. A. Creet)	7·25	32·62	55·00	12·38	6,825	Top 6 ft. 6 in.
	128	Singaran. (Villiers & Co.)	4·90	33·31	52·61	14·08	6,786	
	129	Central Kenda. (Baijnath Ramkumdar & Co.)	9·46	32·00	52·90	15·10	6,448	
	130	New Kenda. (Balmer Lawrie & Co.)	7·47	30·13	49·42	20·45	6,193	
	131	South Kenda. (Goenka Coal Co.)	7·30	30·10	51·45	18·45	6,342	
	132	Khas Kenda. (Khas Kenda Colliery Co.)	10·20	32·40	52·90	14·70	6,724	Bottom 10 ft. 6 in.

TABLE 8.—*Coal analyses—Raniganj measures*—contd.

Name of seam.	No. of analysis.	Name of colliery.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Calorific value. (Calories)	REMARKS.
			Per cent.	Per cent.	Per cent	Per cent.		
Manoharbahal—Rana—Poriarpur—Satgram—Topsi—Kenda—Chora—*contd.*	133	Khas Kenda. (Khas Kenda Colliery Co.)	8·16	33·30	53·50	13·20	6,793	
	134	Kenda Khas. (M. N. Mukerji) .	9·28	31·00	55·60	13·40	6,753	
	135	Chora. (N. C. Sircar) . .	9·04	35·49	52·17	12·34	6,863	
	136	Ditto .	7·82	32·20	53·45	14·35	6,787	
	137	Ditto .	8·95	34·72	51·53	13·75	6,723	
Sonachora . .	138	Sonachora. (Mangalpur Colliery Co.).	7·21	31·60	50·60	17·80	6,212	Bottom 7 ft.
	139	Ditto .	8·62	29·00	51·15	19·85	6,165	9 ft. section.
Jambad—Bowlah .	140	Jambad. (W. C. Bannerji & Co.)	8·82	32·80	52·65	14·55	6,492	Bottom 17 ft.
	141	West Jambad. (Universal Trading Co.).	8·60	33·50	54·70	11·80	6,778	14 ft. 7 in. section.
	142	Lower and Central Jambad. (Bengal Mines & Industries Ltd.).	9·70	31·40	57·40	11·20	6,877	Bottom 14 ft.
	143	South Jambad. (Universal Trading Co.)	8·30	33·80	54·70	11·50	6,807	14 ft. 7 in. section.
	144	Khas Jambad. (Goenka Coal Co.)	10·10	35·00	52·28	12·72	6,661	
	145	Jambad. (North Adjai Coal Co.)	9·60	32·60	57·40	10·00	6,811	Top 8 ft. section.
	146	Ditto .	7·70	32·60	56·00	11·40	6,778	Bottom 8 ft.
	147	Khas Seetalpur. (N. H. Ojha & Co.).	4·37	35·80	53·40	10·80	7,092	
	148	Ditto .	5·40	35·40	53·40	11·20	6,874	
	149	Sitalpur. (Nandwana & Co.) .	4·10	33·63	55·60	10·77	7,326	
	150	Bowlah. (N. C. Sircar) . .	8·47	32·05	48·75	19·20	6,128	Lower part.
	151	Sunkerpur. (Burn & Co.) .	8·63	36·26	50·50	13·22	6,792	Bottom 12 ft.
	152	Jote Dhemo. (K. Amritlal & Co.)	10·30	32·70	52·90	14·40	6,519	
	153	Ditto .	6·50	32·10	57·50	10·40	6,981	Bottom 12 ft.
	154	Bankola. (Bird & Co.) . .	7·45	34·95	51·00	14·05	6,517	
	155	Kumardiha. (M. R. Barry & Co.)	8·00	33·50	52·80	13·70	6,737	8 ft. section.
	156	Ghusick. (Martin & Co.) . .	6·40	32·10	53·65	14·25	6,844	
	157	Kalipahari. (Martin & Co.) .	5·33	30·80	52·05	17·15	6,495	
	158	Ratibati. (Martin & Co.) . .	6·26	30·72	55·40	13·88	6,721	
	159	Chapui. (Gillanders Arbuthnot & Co.)	6·08	29·64	57·94	12·42	6,830	
	160	East Jemahari. (N. Bulkissendass.)	7·70	34·60	54·60	10·80	6,865	
	161	Nimcha. (N. C. Sircar & Co.) .	6·20	34·20	52·70	13·10	6,770	

Nega—Jemeri—Raniganj—Lower Kajora.	162	Ditto .	5·80	31·12	53·40	15·48	6,752	**Top 8 ft.**
	163	Ditto .	6·20	30·20	55·00	14·80	6,827	**Middle 5 ft. 9 in.**
	164	Ditto .	6·40	29·60	55·80	14·60	6,831	**Bottom 3 ft.**
	165	Siarsol. (Gillanders Arbuthnot & Co.)	6·40	32·90	53·90	13·20	6,659	**Middle 13 ft. 6 in.**
	166	Babuisol. (H. V. Low & Co.) .	9·00	35·00	53·70	11·30	7,003	
	167	Babuisol. (N. C. Sircar) . .	7·50	33·40	55·40	11·20	6,796	**13 ft. section leaving 1 ft. in roof.**
	168	Madhabpur. (N. C. Sircar & Sons)	6·48	36·00	50·85	13·15	6,855	
	169	Ditto .	6·80	34·40	53·80	11·80	6,767	
	170	Kajora. (Jadavlal & Sons) .	8·30	33·20	58·30	13·50	6,656	
	171	Kajora. (P. C. Dutt) . .	7·91	30·00	60·28	9·72	7,504	
	172	Kajora. (K. C. Palchowdhury)	7·20	32·80	55·12	12·08	6,859	
Ghusick—Siarsol—Upper Kajora.	173	Ghusick. (Martin & Co.) . .	5·80	32·80	53·10	14·10	6,673	
	174	Muslia. (Martin & Co.) . .	4·10	33·80	53·50	12·70	6,791	
	175	Damra. (Martin & Co.) . .	6·40	35·60	52·80	11·60	6,900	
	176	Damra. (A. Yule & Co.) . .	7·55	34·80	52·60	12·60	6,867	
	177	Ghusick. (C. L. Ghosh & Nephew)	7·05	33·35	54·50	12·15	6,965	
	178	Kuardih. (H. V. Low & Co.) .	5·44	35·80	50·50	13·70	6,708	
	179	Ditto .	5·80	34·40	51·60	14·00	6,554	
	180	Siarsol. (Gillanders Arbuthnot & Co.)	7·50	31·10	52·30	16·60	6,308	
	181	Ghusick. (Martin & Co.) . .	4·38	34·0	50·86	15·14	6,673	
	182	Raniganj. (Sircar & Rees) .	6·62	40·25	49·47	10·28	7,217	Top 11 ft. 6 in.
	183	Damariband. (H. V. Low & Co.)	7·50	33·80	56·00	10·20	6,918	
	184	Upper Kajora. (R. Ghanshamdass & Co.)	6·88	30·36	52·94	16·70	6,510	
	185	Real Kajora. (Sircar & Sircar) .	8·00	35·10	52·50	12·40	6,764	
	186	Pure Kajora. (Pure Kajora Coal Co.)	8·17	34·70	53·40	11·90	6,718	
	187	Madhujori. (Barnard & Co.) .	6·40	37·80	52·00	10·20	7,013	
	188	Ditto .	6·47	37·40	52·80	9·8	6,797	
	189	Darbhanga. (N. L. Dey & Co.) .	7·50	34·90	53·60	11·50	6,857	
	190	Ditto .	7·50	36·60	53·95	9·45	6,911	Top 11 ft.
	191	Khas Kajora. (Shaw Wallace & Co.)	7·00	35·20	56·10	8·70	6,942	Top 9 ft. leaving 3 ft. in roof.
	192	Central Kajora. (A. C. Bannerji & Co.)	7·45	36·15	51·90	11·95	6,739	
	193	South Kajora. (Patel & Mukerji)	7·68	37·40	52·90	9·70	6,995	
	194	Khandra. (Currimbhoy & Co.) .	8·80	34·00	54·20	11·80	6,787	6 ft. section.
	195	Mohira. (Martin & Co.) . .	7·38	28·60	56·80	14·60	6,649	(?=Upper Kajora).
Satpukhuriya . .	196	Satpukhuriya. (Martin & Co.) .	4·67	32·80	55·50	11·70	6,873	
	197	Bonbistopur. (Krishna Coal Co.)	6·50	35·00	53·90	11·10	6,866	
Bharat Chak—Narsamuda	198	Bharat Chak. (B. N. Sanyal) .	4·90	33·00	55·00	12·00	6,739	
	199	Patmohna. (F. W. Heilgers & Co.)	4·80	34·60	53·30	12·10	7,075	
	200	Patmohna. (Shaw Wallace & Co.)	3·41	36·90	52·35	10·75	7,032	
	201	Narsamuda. (Lyall, Marshall & Co.)	6·10	33·30	52·10	14·60	6,619	

CHAPTER XVII.

RESERVES OF COAL.—*contd.*

Statistics.

Output of Coal.

Regarding the output of coal from the Raniganj field since the commencement of mining, a number of statistics are available.

Earliest estimates.

The earliest reference relates to the years 1815-1823, during which time an average annual production of 400 tons was suggested.[1] Estimates are given by the Coal Committee,[2] for the several years previous to 1845, though Mr. Homfray has indicated somewhat higher figures (*see* page 309).

What is probably the first series of accurate deductions, referring to the years 1858-1860, are given by Messrs. Blanford [3] and Oldham.[4]

1858-1860.

During the latter year, 1860, the output of the field was 304,094 tons, of which 171,261 tons were mined in the neighbourhood of Raniganj, and a further 80,792 tons in the Singaran valley. This total represented about 82 per cent. of the output of coal in India at that time. As the years progressed, the output of the Raniganj field steadily increased, and until about 1897 it comprised more than half of the total raisings of the whole of India. With the rapid development of the Jharia field, during the latter part of the past century, however, this proportion fell steadily, and in 1906,

Recent figures.

when the Raniganj output of 3,650,563 tons was exceeded by that of the Jharia mines, it represented only 37·32 per cent. of the total raisings in India. Progress, however, continued at a relatively steady rate within the Raniganj field and during the recent boom period, ending in the year 1919, the output attained the figure of 6,815,126 tons, representing 30·11 per cent. of India's total. As a result of the depression of the year following, these raisings fell to under five million tons. Relatively steady progress has,

[1] 'Notice on the occurrence of coal within the Indo-Gangetic tract of Mountains', by J. H. Herbert, *Asiatic Researches*, XVI, pp. 397-408.
[2] Coal Committee Report, p. 150, (1845).
[3] *Mem. Geol. Surv. Ind.*, III, p. 183, (1861).
[4] *Ibid* Mineral Statistics Coal, p. 7, (1861).

however, again set in during the past seven years, so that at the present time (1929-30), a total output from the field, of the order of 6¼ million tons, has again been reached.

Annual statistics.

The various statistics for the years following 1860 are to be found in a number of publications.[1] Unfortunately, in those referring to the greater part of the period 1880-1897, no separate figure appears to be given for the Raniganj field alone, so that its output can be only approximately computed from the total raisings given for Bengal (at that time including large parts of Assam and Bihar) during those years. Considering, however, that the output of the field during that period was comparatively small, it is probable that the figures, arrived at by the writer, differ to no great extent from the actual raisings from the coalfield. For the present century, however, accurate returns are available.

Total output.

Calculating from these various data, the total output of coal of all grades from the Raniganj field, during the years 1815 to 1929 (inclusive) is of the order of 180 million tons. It is interesting to note that this total agrees very closely with the one recently computed by Mr. Barraclough.[2]

Reserves of Coal.

Previous estimates of reserves.

Various estimates have been given regarding the reserves of coal within the Raniganj field. Doubt has never been expressed concerning the existence of large supplies of non-caking coal of moderate and inferior grades, though considerable discussion has centred around the available resources of caking coal, producing a coke suitable for blast-furnace use, and to a less extent, of superior

[1] 'The Coal Resources and Production of India' by T. Oldham, Esq. (1869).
Mem. Geol. Surv. Ind., Mineral Statistics, VII, Art. 2, pp. 131-150, (1869).
'Manual of the Gelogy of India' by H. B. Medlicott and W. T. Blanford, Pt. 3, (1881), Economic Geology, (V. Ball).
Financial and Commercial Statistics of British India, p. 37, published 1904.
Quinquennial Review of Mineral Production of India, for the years—
1898-1903, *Rec. Geol. Surv. Ind.*, XXXII, pt. 1, (1905).
1904-1908, *Op. cit.*, XXXIX, (1910).
1909-1915, *Op. cit.*, XLVI, (1915).
1914-1918, *Op. cit.*, LII, (1921).
1919-1923, *Op. cit.*, LVII, (1925).
1924-1928, *Op. cit.*, LXIV, (1930).

[2] *Rec. Geol. Surv. Ind.*, LXII, p. 389, (1929).

quality non-caking coals. In 1913, Mr. R. R. Simpson[1] computed the total quantity of first class coal—included in the Dishergarh, Sanctoria and Sibpur (Poniati) seams—at 518 million tons, whilst his figure for medium quality coal—included in the Ghusick, Raniganj, Laikdih and Salanpur seams—was 360 million tons. In comparatively recent years, though previous to the present geological re-survey of the field, the reserves of good quality coals have been estimated by Dr. Fermor to be 689 million tons. Just previous to his recent work in the Damuda valley coalfields, Dr. Fox brought forward certain figures regarding the reserves of caking coals of India in a valuable paper entitled 'The Raw Materials for the Iron and Steel Industry of India.'[2] In the light of more recent investigations, he later revised those estimates, and in 1928,[3] included among

> 'the Indian reserves of coking-coal of good quality, which can be used, either alone or by very careful mixing, for the preparation of coke of metallurgical quality,'

a total of 159 million tons (approx.) from the Raniganj field. In this estimate he included portions of the Laikdih, Ramnagar, and Begunia seams of the Barakar series and of the Dishergarh and Sanctoria seams of the Raniganj measures.

Depths of extraction.

At the present time, a number of collieries are exploiting the better class Dishergarh and Poniati seams, at depths approaching 1,000 feet. This figure is even exceeded in a few collieries and a depth of over 1,500 feet has been reached in the case of the Dishergarh seam at Parbeliya colliery. Large areas of coal, however, remain undeveloped to the rise of these deeper workings. Further to the dip, there is no reason to suggest the discontinuity of the coal seams, though variations in the thickness doubtless take place and have been proved in certain instances. There is, therefore, little doubt that with the advancement of time, deeper shafts will be sunk into the more valuable seams, whilst those of inferior quality might well be exploited from the same pits. The writer has therefore decided to calculate the existing reserves to depths of 1,000 and 2,000 feet, and to make no distinction between the depths to which the various grades of coal might be worked.

[1] *Mem. Geol. Surv. Ind.*, XLI, p. 47, (1913).
[2] *Trans. Min. Geol. Inst. Ind.*, XX, pp. 87-194, (1925).
[3] *Rec. Geol. Surv. Ind.*, LXI, p. 312, (1928).

Classification adopted in present estimate.

In arriving at this estimate of reserves, he proposes to divide the coals into the following three classes:—

(1) Caking coal of superior quality.
(2) Non-caking coal of superior quality.
(3) Coal of inferior quality.

Within class (1) are included those seams, or portions of seams, the coal of which has proved either alone or when carefully mixed with a strongly caking coal, to yield a hard coke suitable for metallurgical purposes. These seams include the Ramnagar, Begunia, Sanctoria and Dishergarh seams, and certain sections of the Laikdih seam, within various limited tracts of the coalfield. The division of the remaining coal seams into classes (2) and (3) has been based largely on the classification adopted by the Indian Coal Grading Board. Of these seams or sections of seams, which comprise the non-caking and weakly-caking coals of the Raniganj field, those regarded as of 'superior quality' are included, in at least the majority of analyses, within either the selected grade or grade I. of the Grading Board's classification. Those of class (3), on the other hand, often fall below the specification required for grade I Needless to say, it would, in this instance, be almost impossible to follow rigidly the Grading Board's classification, for in many cases the same coal seam has proved to belong to different grades at collieries not far distant from one another. For example, portions of the Manoharbahal-Rana-Poriarpur-Satgram seam have in a number of cases been included in grade I, though in other instances, it fails to come up to this standard. Since the seam has also proved to be relatively inconstant over certain areas, it has been relegated to the class of 'inferior quality' coals, though were one computing the reserves in greater detail, the seam, within certain limited areas, might well be included within the class of 'superior quality' coals.

Percentage of total thickness of seam.

Since a certain thickness of coal is often left in the roof during the process of extraction, the full thickness of the various coal seams has not been reckoned in this estimate. Normally about 80 per cent. of the total thickness of coal has been allowed, though in the case of certain of the thinner seams or sections of seams where the coal is

of the convenient workable thickness of about 6 to 7 feet, as much as 90 per cent. has been included in the calculation. In the case of the thick seams, however, particularly in those instances where data regarding the quality of the different sections are not available, a much smaller percentage of the total thickness of coal has been included. It is, therefore, more than probable that these computations err on the side of an under-estimate, and that appreciable quantities of coal, which are now included within the 'inferior' class, will ultimately prove to be of 'superior' type.

Complex faulting and igneous intrusion.

Allowance has also been made in the case of those areas that are markedly affected by complex faulting or igneous intrusion. For this reason, certain tracts of the Barakar measures have been excluded entirely, whilst in the case of others, an allowance of as much as 50 per cent. has been made. No very appreciable loss is incurred in the case of many of the more definite faults. A deduction of five per cent. has, however, been made on the total quantity of coal, which existed previous to the commencement of mining, in order to provide for the loss entailed by those igneous intrusions, which are scattered within the measures.

Specific gravity and dip.

In the case of the caking and superior quality coals a mean specific gravity of 1·375 has been assumed, whilst in the case of those of inferior quality an average of 1·4 has been taken. Where the inclination of the seam is greater than 5° an allowance has also been made.

Final calculations.

On the above-described basis of calculation, estimates representing the total quantities of coal, which existed within the various seams previous to the commencement of mining within the coalfield, within depths of 1,000 and of 2,000 feet have been arrived at on the evidence of the new 4-inch geological maps. From this *original* quantity, the amount of coal that has already been exploited, or which is unlikely to be recovered, has been subtracted. Since, on account of the absence of plans of old workings, it is impossible to apportion this amount accurately among the various individual coal seams, this deduction can only be made from the total amounts of coal that existed within the field. An attempt has, however, been made to apportion this total quantity of extracted and unrecoverable coal among the three different classes into which the Raniganj coals have been divided.

It has previously been mentioned that the total quantity of coal, of all grades, extracted in the past from the Raniganj field, is about 180 millions of tons. In addition to this amount of coal *raised*, large quantities have doubtless been lost during the process of extraction, by fires, collapses, inefficient methods of mining, theft, etc. Mr. Barraclough has shown[1] that the amount of coal lost by fires and collapses, expressed in proportion to the amount of coal obtained, is, in the case of the Raniganj field, 7·73 per cent. The losses that accrue during the process of extraction are more questionable and have been placed by some authorities at 33 per cent. and by others at as much as 50 per cent. The writer proposes to follow the course adopted by Dr. Fox, in the case of the Jharia field, and to regard the total amount of coal rendered unavailable as 50 per cent. of the total quantity obtained from the field. The total amount of coal exploited within the Raniganj field since the commencement of mining is, therefore, estimated at 270 million tons. Regarding the apportioning of this total amount between the three different classes under which the reserves are estimated, the following proportions are suggested :—

Losses during extraction, etc.

Coal already exploited.

(1) Caking coal.	30 per cent. =	81 millions of tons.
(2) Non-caking coal of superior quality.	40 per cent. =	108 millions of tons.
(3) Coal of inferior quality.	30 per cent. =	81 millions of tons.

In this connection it may be mentioned that, although the seams of caking coal are few in number, the Dishergarh and Sanctoria seams, which are included in this class, have been exploited to a large extent, and have represented a big percentage of the total output during the past 60 years.

Calculating on the above basis, the original quantities of coal included within the seams of the Raniganj field to depths of 1,000 and 2,000 feet are set out in the following tables in the three above-mentioned classes ;—caking coal of superior quality, non-caking coal of superior quality and coal of inferior quality. From the totals of these three classes the amounts that have already been exploited have been deducted, the resultant quantity representing the total reserves of coal of the three separate grades.

[1] *Rec. Geol. Surv. Ind.*, LXII, p. 389, (1929).

Since a certain, relatively small, proportion of the output has been obtained from depths greater than 1,000 feet, it is probable that the reserves, which refer to that depth, are slightly underestimated.

TABLE 9.—(1) *Caking coal of superior quality.*

Name of seam.	ORIGINAL QUANTITY (EXPRESSED IN TONS).	
	To a depth of 1,000 feet.	To a depth of 2,000 feet.
Ramnagar	12,066,000	22,227,000
Laikdih	18,343,000	31,298,000
Begunia	12,193,000	26,672,000
Sanctoria	13,336,000	13,336,000
Dishergarh	106,853,000	237,372,000
Original total :	162,791,000	330,905,000
Amount already exploited :	81,000,000	81,000,000
PRESENT RESERVES :	81,791,000	249,905,000

TABLE 10.—(2) *Non-caking coal of superior quality.*

Name of seam.	ORIGINAL QUANTITY (EXPRESSED IN TONS).	
	To a depth of 1,000 feet.	To a depth of 2,000 feet.
Damagaria—Salanpur 'A'	62,006,000	99,156,000
Gourangdi—Kasta	24,475,000	43,020,000
Shampur '5'—Laikdih—Bahira '3'	43,156,000	113,736,000
Top Fotka—Chanch—Begunia	27,294,000	57,078,000
Sanctoria-Poniati	170,335,000	324,379,000
Dishergarh	29,060,000	152,170,000
Samla	131,582,000	131,582,000
Raghunathbati	8,764,000	8,764,000
Jambad—Bowlah	132,090,000	132,090,000
Nega—Raniganj—Lower Kajora	261,766,000	307,490,000
Ghusick—Siarsol—Upper Kajora	172,225,000	300,374,000
Satpukhuriya	8,891,000	8,891,000
Original total :	1,071,644,000	1,678,730,000
Amount already exploited :	108,000,000	108,000,000
PRESENT RESERVES :	963,644,000	1,570,730,000

TABLE 11.—(3) *Coal of inferior quality.*

—	ORIGINAL QUANTITY (EXPRESSED IN TONS).	
	To a depth of 1,000 feet.	To a depth of 2,000 feet.
Original total :	4,712,142,000	6,940,291,000
Amount already exploited :	81,000,000	81,000,000
PRESENT RESERVES :	4,631,142,000	6,859,291,000

The following notes regarding the considerations involved in the above estimates might be recorded.

Damagaria-Salanpur 'A' seam.

In the case of the Damagaria-Salanpur 'A' seam, only the lower portion of the seam included within the Damagaria-Banbirdi area, and to the dip within the Bahira tract, has been regarded as of superior quality. It is well known that the seam decreases in quality in the vicinity of its outcrop to the east, though no information is available regarding the nature of the coal to the dip of these outcrop workings. To be on the safe side, therefore, this latter coal has been included among the inferior grades.

Laikdih and Ramnagar seams.

Concerning the amount of caking coal included within the Laikdih and Ramnagar seams, in the case of the former, a thickness of 12 feet has alone been regarded as of metallurgical quality. In addition, only the areas between the Barakar river and the dip-fault, which separates Lalbazar and Bahira collieries, have been included in this estimate, due allowance being also made for the extensive mica-peridotite sill intrusions of the Barakar-Balltara area, and for the strike-faults, which run south of Begunia village. Similar allowances have been made in the case of the Begunia seam.

Sanctoria-Poniati seam.

In the case of the Sanctoria seam, the area north of the Damodar river, to the west of Chhota Dhemua (Chhota Dhemo) has alone been included in the above estimate of caking coal. The area east of Chhota Dhemua, to within a short distance of Chinchuria colliery has, on account of the proved existence of mica-peridotite intrusions, been entirely excluded. In the case of the Poniati seam, the estimates are again limited by the evidence of the marked thinning of the coal seam both to the east and to the dip, within the Damodarpur-Banali area.

The caking qualities of the Dishergarh seam, at least as far east as Bara Dhemo and as far south as Saltor, have been amply demonstrated.

Dishergarh seam.

The quality of the seam to the dip, at Parbeliya colliery, is equally good and there is no reason to suggest its deterioration at greater depths. To the south-west of Deilya (Deoli) the coal is somewhat inferior, though it is quite possible that further to the dip it will be found to have improved. Excluding the area with intrusions between Sitarampur and Ganrui, the writer has, therefore, regarded the coal within the area north of the line of the Deoli-Murulia fault as of caking quality. A portion of the seam to the south of this fault has been included in the 'superior quality' coals, though it is quite possible that this also may prove to be of use in the production of metallurgical coke. Should such prove to be the case, the reserves of caking coal would be very materially increased. It is also probable that within the area of Raniganj outcrops between Gorangi and Biharinath hills, the Dishergarh seam will be met with at a depth of not more than 2,000 feet (*see* page 198).

In the north-eastern part of the coalfield, the Samla seam has been proved over a fairly wide area. On account of the lack of deep bore-

Samla seam.

holes to the dip, no allowance has been made for the possibility of the continuation of this seam beyond a depth of 1,000 feet, while only the lower section of the seam has been regarded as of superior quality.

In the case of the Raghunathbati seam only the limited area between Luchhipur and Sarakdih and for a short distance to the

Raghunathbati seam.

dip, has been included in class (2).

Only the lower 12 to 14 feet of the thick Jambad-Bowlah seam have been included in this estimate of superior coals, though it is

Jambad-Bowlah seam.

probable that other sections of the seam will prove to be of good quality. To the east, the seam appears to decrease somewhat in thickness and in quality and has therefore, in the unproved area east of Bankola, been excluded from the class of high grade coals.

The Nega-Raniganj-Lower Kajora seam, together with the Ghusick-Siarsol-Upper Kajora seam, persists over wide areas to the

Nega and Ghusick seams.

north of the Damodar river with remarkable constancy, large portions of these areas being so far undeveloped. From 7 to 9 feet of each

of these seams have been reckoned in the estimate of superior coals. In the case of the Satpukhuriya seam, only the coal of the area in the vicinity of Satpukhuriya has been included in this class.

With regard to the inferior quality coals, the calculation has been largely limited to those seams or portions of seams that have, at least in certain parts of the coalfield, proved of economic value. In the case of the thicker coal seams, a reserved estimate of the thickness of such workable coal has been allowed. Were one to include in this calculation the total thickness of inferior coal, which has been indicated from bore-hole records to exist within the measures, the total reserves would probably be more than double that which is given in the above estimate. Such, however, would be misleading, for it is probable that a considerable proportion of this so-called 'coal' will prove of too inferior a quality to be of economic value.

Inferior coal.

Reviewing the coal reserves of the Raniganj field (as included within the above table), it is observed that the quantity of coal that *without admixture* yields a coke of metallurgical quality, and which is limited to the Ramnagar and portions of the Laikdih seams, is decidedly small. Adding to this total, however, those reserves of good quality coal which, when mixed with a strongly-caking low-volatile coal, have proved to yield a valuable hard coke, the quantity—derived largely from the Dishergarh seam—becomes immensely larger and of very appreciable importance, reaching a total of nearly 82 million and 250 million tons within depths of 1,000 and 2,000 feet, respectively.

Concluding remarks.

In the class of other superior quality coals, the greater proportion of which are non-caking, reserves of about 963½ million and 1,570¾ million tons, within depths of 1,000 and 2,000 feet respectively, are suggested.

Of inferior quality coals, the present estimates fully confirm the conclusions arrived at by early investigators; namely, that the reserves of this type are enormous, probably unlimited in so far as the coal-mining industry is concerned.

It is not proposed to enter into the question of what proportion of these valuable coal resources are likely to be rendered available for public use during future years. The answer to such a question obviously hinges on the methods of mining that will be adopted during the process of extraction of these reserves. It is, however,

U 2

well known to all who are closely acquainted with the present coal-mining industry of India, that without considerable advancement, of which the principal is, probably, the adoption of sand-stowing as a general rule, a very appreciable and important proportion of the above totals will be lost entirely during the exploitation of the remainder.

CHAPTER XVIII.

DEPOSITS OF IRON-ORE.

Early optimism unjustified.

At one time, previous to the discovery of the more valuable products of the Singhbhum area, the deposits of iron-ore that exist within the Raniganj coalfield ranked highly as a possible source for the future establishment of a large iron industry in Bengal. Unfortunately, this early optimism has not so far been justified, for, only to a very limited extent have these ores been proved to be of economic worth. That these deposits were, however, used on a relatively large scale by the *agarias* in the old days, is evidenced by the number of large mounds of slag and refuse that are found scattered at intervals over various parts of the coalfield.

These deposits of iron-ore include :—

(i) Clay-ironstones of the Middle Damudas. (Ironstone Shales).
(ii) Lateritic ores of the eastern portion of the coalfield.
(iii) Magnetite ores within the metamorphics a short distance south of the coalfield.

The details of these various deposits are as follows :—

(*i*). *Clay-ironstones of the Middle Damudas.* (*Ironstone Shales*).

Motte & Farquhar, 1777.

The earliest official reference to these deposits, as a possible source of ore for the manufacture of iron, was included in the proposal to Government by Messrs. Motte and Farquhar, in the year 1777 (*see* p. 1). The efforts of these early pioneers were, however, attended with no success in so far as the Raniganj field was concerned.

David Smith, 1856.

In 1856, the deposits of the eastern part of the coalfield were reported on by Mr. David Smith who, at the instigation of Government, was deputed to carry out an examination of the iron-bearing areas of Bengal.[1] His efforts were largely confined to the 'Barrool field' between Churulia, Jamsol and Sattar, where, about half a mile west of Barul village, he sunk a shaft to a depth of about 52 feet in the Ironstone Shale measures. Within the top 32 feet of strata four seams of clay-ironstone were encountered, of an

'Barrool field.'

[1] Mr. David Smith's Report to the Government of India on the Coal and Iron districts of Bengal, pp. 76-79, (1856).

aggregate thickness of 18 inches, together with a 52-inch band of 'black-band' ore, all of which he regarded as being of good quality, capable of being used in the blast-furnace. In the lower part of the shaft, another seam of ore was proved, 28 inches in thickness and yielding 42 per cent. of iron on analysis. He estimated that the deposits of this portion of the coalfield would yield 6,400,000 tons of ore, per square mile. This calculation was apparently based on the assumption that all the beds of ore, which had been proved within the shaft, would continue in thickness throughout the whole area.

Mr. David Smith also noted the occurrence of three or four seams of ore within the Ironstone Shales of the 'Taldanga field', lying east of the Barakar river between the 146th and 148th milestones of the Grand Trunk road; together with a band of ore, which was being worked by the native smelters about 1½ miles west of the Barakar, evidently within the Barakar measures. He was, however, in favour of the establishment of iron-works within the vicinity of either Raniganj or Barul, the one area containing coal (which he regarded as suitable, provided it were used in the raw condition in a furnace with a blast heated to 600° F.) and the other including iron-ore in 'inexhaustible abundance'.

'Taldanga field.'

In 1860, Dr. Blanford, during the course of his survey, briefly describes the deposits of the Middle Damuda measures. He points out the inaccuracy of Mr. David Smith's assumption that the seams of ironstone are necessarily continuous throughout the whole of the Ironstone Shale area. In the case of the exposures near Jamsol, he notes the occurrence of 26 bands of ironstone included at intervals of from six inches to 10 feet from each other, and varying in thickness from two inches up to about one foot. These bands were exposed within a total thickness of 150 feet of the measures, so that the ironstone represents about one-seventeenth of the whole. This, he regards as probably about the average for the upper part of the measures. From a number of analyses, he illustrates the variability of these ores as regards the percentage of iron that they contain, ranging from 18·00 to 53·96 per cent. He observes that this proportion differs considerably even in the case of specimens taken from about the same locality.

Blanford, 1860.

During the latter part of the year 1872, Mr. H. Bauerman, who had been sent out by the Right Hon'ble the Secretary of State for India, visited the more important iron-yielding districts (amongst others, the Raniganj field)

Bauerman, 1872.

with a view to giving a definite opinion on the feasibility of establishing ironworks in India. Regarding Mr. Bauerman's visit Mr. Medlicott writes[1] :—

'Mr. Bauerman has simply restated the case ...... that, under existing circumstances, the Raniganj coal field is the most promising place for a trial, the principal defect there being the flux.'

Hughes, 1874.

In February 1874, Mr. W. H. Hughes published a comprehensive 'Note on the Raw Materials for iron-smelting in the Raniganj field.'[2] Regarding the resources of iron-ore, Mr. Hughes estimated an average of one foot in every 10 to 12 feet of shale, and taking the total thickness of the measures as 1,000 feet, he calculated a supply of ore of the order of 200 million tons in every square mile. In a further note, published the same year,[3] he includes the following table of analyses of samples of ironstone collected in the western part of the coalfield.

TABLE 12.

—	Begunia No. 1.	Begunia No. 2.	Boldih.	Chalbalpur.	Kulti.	Malakola.	Sibpur.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Insoluble . .	13·6	10·6	20·4	14·8	19·6	18·8	21·2
(Silica) . .	(11·6)	(8·6)	(16·8)	(12·1)	(16·4)	(16·2)	(17·0)
Sesquioxide of Fe	65·44	53·2	52·28	66·45	60·1	62·92	43·82
Protoxide of Fe	..	13·48	1·08	..	..	..	8·92
Alumina . .	6·25	4·07	5·89	4·7	5·8	3·91	5·17
Lime . .	0·8	1·0	4·03	2·24	2·9	2·88	3·36
Magnesia . .	0·7	0·85	1·8	(a)	0·6	(a)	(a)
Phosphoric acid	0·71	0·57	1·43	2·05	2·2	2·57	2·3
Sulphuric acid .	..	0·55	..	(a)	..	(a)	(a)
Loss on ignition	13·5	16·0	13·2	9·6	9·2	10·2	14·4
TOTAL .	101·0	100·32	100·15	98·84	100·7	101·28	99·17
Metallic iron .	45·80	47·72	37·43	46·5	42·28	44·03	37·60

(a) A little magnesia and sulphuric acid occur in the Chalbalpur, Chinakuri, and Malakola ores. Being small it was not quantitively determined.

[1] *Rec. Geol. Surv. Ind.*, VII, p. 6, (1874).
[2] *Op. cit.* p. 20.
[3] *Op. cit.* p. 122.

An abstract of the phosphorus contained in these samples shows that the minimum quantity is 0·232 while the maximum is 1·122 per cent. He observes that the proportion of iron is much larger than that contained in the bulk of the ores in England.

Walker, 1913.

In 1913, Mr. Walker[1] in his 'Note on the Geological Re-Survey of the Raniganj Coalfield', included a further table of analyses (supplied by the General Manager, Bengal Iron & Steel Co., Ltd., Kulti) of the iron-ores of the Ironstone Shale measures. This table of analyses is reproduced in Table 13.

Use of Raniganj ironstones in past years.

The site of the Barakar Iron works was originally chosen on account of the proximity of both coal and ore deposits. The outcrop of the Ironstone Shales stretches east and west from the works, and for many years the clay ironstones from these beds constituted the only supply of ore used in the blast-furnaces. After 1906, these Raniganj ores were first mixed with pure magnetite from the deposits of Turamdih, south of Tatanagar, but since 1914, the employment of the clay-ironstones has been totally discontinued. In 1913, Mr. Walker mentions, 'that roughly 7,000 tons of iron-ore, drawn from the Ironstone Shales, were used annually in the furnaces', at Kulti. The ore mainly included the partially oxidised rectangular boulders of reddish-brown ironstone that were collected from the weathered surface of the Ironstone Shale measures.

The Ironstone Shale ores.

As has been previously observed, these measures include a total thickness of about 1,200 feet of shales with ironstone, and reckoning also those areas that are hidden by a capping of soil or alluvium, their main outcrops between the Barakar and Adjai rivers comprise a total area of about 44 square miles. The bands of clay-ironstone are by no means regular in habit. They occur at intervals of a few inches to several feet, and vary in individual thickness up to about 18 inches. Lateral variation is marked within the individual bands, which are often lenticular in shape and pass laterally into 'black-band' ore, or into the grey carbonaceous shales that constitute a large proportion of the measures. As certain bands die out, however, others usually come in at slightly different horizons so that the general average percentage of ore remains approximately the same. Grey shales, approaching indurated fireclays in type, also occur at intervals.

[1] *Trans. Min. Geol. Inst. Ind.*, VII, p. 276, (1913).

TABLE No. 13.—ANALYSES OF IRONSTONE.

Locality and number of analyses.

	West of the Barakar extending to the Pandra Estate.	Local ore from near Kulti up to Ethora.	Churulia area from Jamagar to Toposi.
	6 analyses.	6 analyses.	7 analyses.
Iron—			
Maximum value	47·70	43·40	43·50
Minimum value	39·00	41·30	41·80
Average value	45·25	42·41	42·91
Silica—			
Maximum value	21·80	19·40	17·40
Minimum value	18·40	16·70	16·00
Average value	19·90	17·56	16·70
Phosphorus—			
Maximum value	1·37	0·86	1·15
Minimum value	0·23	0·79	0·64
Average value	0·44	0·82	0·90
Manganese—			
Maximum value	1·60	1·90	3·62
Minimum value	0·57	1·61	2·56
Average value	0·93	1·78	2·85
Moisture—			
Maximum value	2·20	1·90	5·10
Minimum value	1·00	1·00	1·30
Average value	0·68	1·80	2·84

In depth, the ore is of a greyish colour, and, as has been suggested by Dr. Fermor,[1] it is apparently largely composed of carbonate. Within a few feet of the surface, however, these grey ironstones undergo oxidation and weather into rectangular-shaped blocks of a reddish-brown colour. It was these oxidised ironstones that were apparently used with considerable success in the Kulti blast-furnaces. No recent information is, however, available regarding the nature and quality of the hydrated and less-oxidised ores, which continue to the dip of these outcrops, and in consideration of the occurrence of immense deposits of high grade hematitic and magnetite ores within other parts of north-eastern India, it is very doubtful whether the Ironstone Shale products will again prove of economic value for many years.

[1] *Trans. Min. Geol. Inst. Ind.*, XX, p. 363, (1926).

Without further information regarding the probable utility of these deeper deposits, it is therefore impossible to arrive at any definite figure regarding the reserves of workable iron-ore within this area. That large quantities exist, of a type suitable for the production of iron, is undoubted, though the practicability of exploiting these reserves underground, is, at least for many years, more than improbable.

Reserves of ore.

In addition to these measures, similar hematitic clay-ironstones occur in minor quantity associated with the shales of the middle and upper Barakars, particularly in the eastern part of the coalfield; and to a small extent within the upper Raniganj strata. These ironstones have been used in the distant past by the native smelters of the indigenous iron-industry.

Ironstones of the Barakar and Raniganj measures.

(*ii*) *Lateritic ores of the eastern portion of the coalfield.*

The nature and extent of these lateritic deposits have already been described. On the whole, they are highly siliceous and pass laterally into quartzitic conglomerates the pebbles of which are enclosed in a hematitic matrix. These ferruginous laterites were regarded by Mr. David Smith as 'valuable ore' which could 'be advantageously used with other clay ores of the districts in the manufacture of iron.'[1] This view has, however, proved to be unjustifiably optimistic, for the ores have so far proved to contain not more than about 25 per cent. of iron, and it is very doubtful whether even this figure would be reached in the case of the greater proportion of the deposit.

Highly siliceous.

(*iii*) *Magnetite ores within the metamorphics a short distance south of the coalfield.*

Outside the actual limits of the coalfield, within the metamorphics, Dr. Blanford[2] notes the occurrence of:—

> 'very rich deposits of magnetic iron associated with metamorphic quartzite just beyond the south boundary of the field, near the village of Tituri, about 2 miles west of Beharinath Hill. The ores occur interlaminated with the quartzite and gneiss, in bands varying in thickness from 3 inches to 2 feet. They are very pure, and contain from 60 to 70 per cent. of iron.'

[1] Mr. David Smith's Report to the Government of India on the Coal and Iron districts of Bengal, p. 76, (1856).

[2] *Mem. Geol. Surv. Ind.*, III, p. 193, (1861).

CHAPTER XIX.

DEPOSITS OF FIRE AND OTHER CLAYS.

(a) Fireclay.

Occurrence within Barakar measures.

A number of seams of fireclay of very good quality occur within the lower and middle measures of the Barakar series. They have been extracted for a number of years and used in the manufacture of firebricks at the various works within the coalfield. The seams vary up to several feet in thickness and are usually associated with hard massive grits and sandstones, constituting an over-burden that is very expensive to remove. These overlying rocks have so far impeded the exploitation of the seams to any great distance beyond the actual outcrop, though on account of the limited occurrence of deposits of a high grade quality, it is anticipated that the extension of these workings underground will be found necessary at no distant date. It is probable that, at least in some instances, the seams of fireclay will thicken to the dip. In some cases, the clays grade into carbonaceous clays and impure coal, and in the instance of the weathered outcrop of the Damagaria coal seam, the coal of the upper and middle portions of the seam appears to pass up into grey clays, at least approaching fireclay in appearance.

Localities.

The principal areas within which these beds occur, include the outcrops of the Garphalbari-Dahibari grits and coal measures to the north and south of the Kudia *nala*; the equivalent rocks to the south-east of Damagaria; the lower measures of the Radhaballavpur-Shyamdi-Pahargora area; the Ramdhara-Kantapahari area; the Garh Dhemo-Churulia area; and the lower Barakar outcrops of the Trans-Adjai area.

Previous note on Raniganj firebricks.

Mention has already been made of the occurrence of these deposits, by Messrs. Hughes and Medlicott,[1] whose report, regarding the quality of the firebricks, which were manufactured from the clays, was highly favourable. The industry is at the present time in a flourishing condition and the products obtained have been proved amply to satisfy the requirements of the present iron and steel trades of India.

[1] *Rec. Geol. Surv. Ind.*, VIII, p. 18, (1875).

In addition to these deposits, thick seams of shaly clays, including various percentages of carbonaceous matter, occur within the coal measures of the Raniganj field, and bands of grey clay-shale, approaching indurated fireclays in appearance, crop out within the Ironstone Shale measures on the north side of the Grand Trunk road to the south-west of Kulti. The suitability of certain of these deposits, after being calcined, is so far unknown, though it is possible that, with the exhaustion of the known outcrops of the purer types of fireclay, attention will have to be paid to the above-mentioned deposits.

Occurrences of carbonaceous clays.

Typical analyses of good quality fireclays, (worked by Messrs. Bird & Co.) are as follows:—

Analyses of fireclays.

	Gourangdi.	*Patlabari.*
	Per cent.	Per cent.
SiO_2	50·48	53·58
Al_2O_3	35·06	30·88
Fe_2O_3	0·64	0·68
CaO	0·33	0·28
MgO	0·20	0·22
Na_2O	0·04	0·25
K_2O	1·09	1·15
Loss on ignition	12·12	12·98
	99·96	100·02

(Analyses by Dr. E. Spencer.)

(b) Other clays.

These deposits include the carbonaceous clays of the Ronei area to the north-east of Raniganj, the light coloured clays of Durgapur and the extensive deposits of argillaceous alluvium on which the native brick and tile industry depends.

Within the laterite-capped ridge, in the vicinity of Ronei village, dark grey carbonaceous clays, approaching very inferior fireclays, are worked by Messrs. Burn & Co. for their Pottery works at Raniganj. These clays occur as a seam, from three to four feet in thickness, a short distance south of the village, and being almost horizontal they apparently extend beneath the alluvium of the small valley to the north-east and are again met with in the next ridge, to the south-east of Ronei. This seam is considered, by the writer, to represent an impure fire-

Carbonaceous clays of Ronei.

clay included within the upper part of the Raniganj measures. This assumption is borne out by the section in the pits south of Ronei, where the associated strata include :—

Laterite	3 to 4 feet.
Soft, decomposed, yellow-grey sandstone passing down into less altered sandstone of Raniganj type . . .	(thickness varies in the different pits).
Dark grey, carbonaceous clay	3 to 4 feet.

The overlying sandstone, being relatively soft, it is practicable to quarry these clays to a greater depth than has so far been found possible in the case of the fireclays of the Barakar measures.

Outcrops near the Grand Trunk road.

To the north and east of Ronei, in the vicinity of the Grand Trunk road, light grey clays have been quarried in the past. It is doubtful whether these latter deposits are directly associated with the laterite of the vicinity, or should be regarded as weathered outcrops of certain argillaceous bands of the upper Raniganj measures.

Clays of Durgapur.

Reference has already been made to the light-coloured clays of the Durgapur area (*see* p. 62). These beds crop out within the large excavations to the north of the railway, and are also exposed as seams up to several feet in thickness, intercalated among the Durgapur sandstones of that locality. The clays are utilised at Messrs. Burn & Co.'s Durgapur works for the manufacture of building bricks and tiles, for which purpose they are, apparently, excellently suited. In the present main pit to the north of the Durgapur brick works, these clays attain a workable thickness of about 18 feet, and in the south-eastern excavation (now flooded) as much as 30 feet was reported.

Clay deposits of an inferior grade.

In addition to these relatively high grade deposits, large areas of argillaceous alluvium occur within the coalfield. From this alluvium bricks and tiles are manufactured by open burning, at a number of places. These products, many of which are of a very inferior quality, supply the needs of the local population.

CHAPTER XX.

DEPOSITS OF RIVER-SAND.

In so far as the deposits of river-sand are concerned, the Raniganj field is singularly fortunate. Except in the case of a few collieries, little advantage has been taken of the occurrence of these immense quantities of material, admirably suited for sand-stowing. It is probable, however, that if the coal seams are to be extracted with a minimum amount of waste and the reserves of coal already indicated are to be realised, then greater attention will have to be paid to these sand deposits during the future development of the coalfield. The importance of this question has been pressed home by a number of mining authorities in the case of the Jharia field, and similar comments might be applied with equal force to the Raniganj area.

Use in sand-stowing.

The available quantities of sand within any river system might be classed as follows :—

Types of deposits.

(i) Those relatively constant quantities that exist within the system.
(ii) Those transitory quantities that are transported by the river—particularly during periods of flood—and are ultimately carried down to the sea.

These two classes of deposits are obviously inter-connected and to some extent interchangeable, though the first, unless affected by a sudden change of conditions, such as earth-movements, a general increase or decrease in the flow of the river-system, or human agencies, remains as a whole relatively constant over long periods.

A glance at the wide areas of river-sand exposed within the limits of the existing banks of the Barakar, Damodar and Adjai rivers during the dry season is sufficient to convince one that immense quantities of the former, relatively stationary type of deposit, are available.

Regarding the amounts of these comparatively permanent deposits of river-sand, the following calculations have been made.

1. *The Barakar river.*

The length of the Barakar river within the precincts of the Raniganj field, that is to say, from just west of Duburdih village southwards to its junction with the Damodar, is about 6¼ miles, whilst the

average width of sand included between either bank is about 570 yards. Regarding the thickness of the deposits the following data are available.

Thickness of river-sand—

(*a*) To the west of Ramnagar village, three bore-holes, located within the eastern half of the river, proved the total thickness of sand and gravel, at increasingly greater distances from the river-bank, to be 61, 80 and 94 feet respectively.

(*b*) Bore-holes located near the East Indian Railway bridge proved the following :—

Nature of deposit.	Distances from the eastern river-bank (in feet).				
	75	125	225	275	325
	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
Fine sand . . .	6 0	6 0	6 0	6 0	6 0
Coarse sand mixed with gravel.	12 0	13 0	13 0	13 0	14 0
Fine sand . . .	2 0	2 6	2 6	3 0	2 0
Coarse sand mixed with pebbles and gravel.	8 6	9 0	29 6	23 0	33 0
TOTAL THICKNESS .	28 6	30 6	51 0	45 0	55 0

(*c*) Bore-holes located west of Begunia village, proved the following :—

(1)

	Ft.	in.
Sand	47	6
Coarse sand	2	6
Mud	3	0
TOTAL .	53	0

(2)

	Ft.	in.
Clay	20	0
Sand	22	0
Coarse sand	8	0
TOTAL .	50	0

(3)

	Ft.	in.
Sand	56	0
Sand with gravel . .	24	0
Coarse sand . . .	5	0
TOTAL .	85	0

(4)

	Ft.	in.
Sand	58	0
Coarse sand	17	0
Sand	9	0
TOTAL .	84	0

(Bore-holes 3 and 4 were put down near the middle of the river-bed ; 1 and 2 were located near the river-bank.)

Further south, in the approach to the Damodar, no direct evidence is available, though on account of the diminution in the velocity of

the currents, which would be expected to take place near the junction of these two rivers, it is probable that at least equally great thicknesses of sand with gravel exist.

In allowing, therefore, an average thickness of 40 feet of sand and gravel (including a small proportion of clay) over the length of this portion of the river, we are probably erring considerably on the side of an under-estimate.

Calculating from the above-noted data, the total volume of these deposits of the Barakar river, within the precincts of the Raniganj coalfield, equals about 2,265 million cubic feet.

2. *The Damodar river.*

With regard to the Damodar river, direct evidence is available only within the vicinity of Saltor colliery, at which locality the depth of sand was proved, in a number of bore-holes located between the southern mainland and Saltor island, to vary from a few feet up to a maximum of 80 feet near the centre of the river. Excluding the several islands, composed of sand and gravel, which occur within the present river-bed, the total area covered by river-sand within the Damodar, from its point of entry into the coalfield near Kelyasota, to its approximate exit at longitude 87° 12′ to the south of Andal, is about 13 square miles. That the deposits of sand, with gravel and a small proportion of alluvial clay, are of a very great thickness within at least large portions of this area, is undoubtedly true, and an average of 30 feet can safely be allowed as a minimum figure. This represents a total volume of about 10,873 million cubic feet.

Thickness of river-sand.

Area of river sand.

3. *The Adjai river.*

In the case of the Adjai river, the only statistics available are the details of the bore-holes that were put down in the river-bed along the alignment of the East Indian Railway bridge just north of Pandaveswar station. The bore-holes show that, although the river-sand is underlain by a stiff clay at depths of from 10 to 30 feet in the vicinity of the banks, the thickness of sand increases very rapidly to over 90 feet near the centre of the river. From the widespread nature of the deposit, and from the evidence of the above-mentioned bore-holes and of those within the alluvial tracts to the north of the present river-bed, an

Data.

average thickness of at least 25 feet is suggested within that portion of the river that traverses the Raniganj field, for a distance of about 21 miles between Pariarpur in the north-west to longitude 87° 20′ in the east.

Again excluding the alluvial islands, which exist within the present river-bed, the total volume of river-sand of this section of the Adjai is in the neighbourhood of 5,619 million cubic feet.

Summarised, these totals are as follows :—

Locality.	Quantity in millions of cubic feet.
Barakar river	2,265
Damodar river	10,873
Adjai river	5,619
TOTAL	18,757 million cubic feet.

In addition to these deposits, large quantities of sand and gravel exist over wide areas adjoining these rivers, within various tracts of the coalfield.

Transitory deposits.

It is well known that large volumes of sand, which have accrued in the upper courses of these rivers during the progress of weathering and erosion, are transported down to the lower reaches of the rivers within and beyond the precincts of the coalfield during the monsoon season. The condition of the water during that period bears evidence of this phenomenon. This has again been demonstrated in all instances in which large excavations have been made within the beds of these rivers, particularly so in connection with the sand-stowing arrangements at Saltor colliery. In every case, these excavations were re-filled with sand within a short period of the commencement of flood. Again, further downstream, in the vicinity of Burdwan, the Damodar has, apparently, for many years been gradually silting up as the result of the deposition of sand brought down during the monsoon, so that in some places, the river-bed is at a higher level than portions of the surrounding country. Even should large quantities of sand be removed from the higher reaches of the river, within the more western coalfields of the Damodar valley, during the near future, it is very improbable that these quantities will, at least for many years, be sufficiently immense to materially decrease the volume that is now being brought down by the river within the Raniganj area.

It can safely be stated, therefore, that within the Raniganj field, there exists a quantity of river-sand which, in combination with the transitory supply brought down by the rivers during periods of flood, will be more than sufficient to meet the demands of the mining industry, even though sand-stowing be introduced on an extensive scale.

The question of sand-stowing in Indian mines has been recently discussed by Mr. J. Mackie.[1] Referring to the immense quantities of coal that are now standing in pillars in the coalfields of Raniganj and Jharia, he states :—

'Some of these pillars will take 100 cu. ft. of sand for the recovery of say 60 cu. ft. (approx. 2·3 tons) of coal where solid packing is required, while in cases where less stowing is necessary it will always take 60 cu. ft. of sand for 50 cu. ft. (approx. 1·9 tons) of coal.'

In the case of a virgin area however, he observes that only 0·54 tons of sand are required for the recovery of 1 ton of coal.

[1] *Capital*, 23rd May, 1929.

CHAPTER XXI.

LIMESTONE AND KANKAR; BUILDING-STONE; ROAD-METAL.

(i) Limestone and Kankar.

Reference has already been made to the deposits of limestone that occur within the lower Panchet strata, near Baghmara, to the west of Panchet hill. These deposits, together with certain crystalline limestone outcrops within the metamorphics near Hansapathar, 10 miles further west, have been described by Mr. Mallet.[1]

Deposits near Baghmara.

The Baghmara deposits occur within the low ground between the main boundary fault of the coalfield and the western end of Panchet hill, dipping E. 30° S. at 15°; the limestone was extracted in the past from small quarry-workings. Within the most northerly quarry Mr. Mallet observed massive, bedded, dark-grey limestone at least 11 to 12 feet in thickness, whilst in the southern working, a band of arenaceous limestone, of a thickness of 18 feet is mentioned.

These two outcrops yielded the following analyses :—

	Limestone of northern quarry.	Arenaceous limestone of southern quarry.
	Per cent.	Per cent.
Calcium carbonate .	63·40	45·05
Magnesium carbonate .	11·11	11·53
Ferrous carbonate. .	4·15	3·61
Ferric oxide . .	0·62	0·28
Phosphoric acid . .	0·12	0·07
Insoluble . . .	19·28	39·28
	101·98	99·85

Deposits of Hansapathar.

Half-a-mile west of Hansapathar, an outcrop of limestone was quarried on a small scale. The limestone was reported to be from 70 to 80 feet in thickness of which three to four feet were of good quality. A short distance north

[1] *Rec. Geol. Surv. Ind.*, X, p. 148, (1877).

of Hansapathar, a second 25-foot band was observed, whilst a third is mentioned to the north of Asta village, as much as 150 feet thick. The limestone is apparently white, crystalline, from fine to coarse-textured, including strings and nests of quartz and felspar, and disseminated crystals of actinolite. Two analyses of this stone are given as follows :—

	Per cent.
$CaCO_3$	83·43
$MgCO_3$	0·78
$FeCO_3$	0·68
P_2O_5	0·02
Insoluble matter	16·18
	101·09

	Per cent.
$CaCO_3$	67·30
$MgCO_3$	0·57
Fe_2O_3, Al_2O_3	0·73
P_2O_5	0·09
Insoluble matter	31·31
	100.00

Other occurrences.

Other reported occurrences of limestone include an outcrop of unknown extent at Jamuan,[1] six miles south of Raniganj, together with a dolomitic limestone near Ramlallpur,[2] seven miles south of Raniganj.

The deposits of Baghmara and Hansapathar were, apparently, used as a flux on a small scale, during the early days of the Barakar furnaces.

Deposits of tufa and kankar.

The tufaceous and kankar deposits of the Raniganj field, by reason of their possible utility as a flux in the manufacture of iron, have for a long time attracted the attention of geological and metallurgical observers. The deposits on the banks of the Barakar river near Ramnagar, and east of Dumarkanda were noted by Dr. Blanford.[3] In addition, as a result of the weathering of the softer types of sandstone of Raniganj and Panchet horizons, small irregularly-shaped fragments of kankar are disseminated over the surface of the soil-capping, which overlies these rocks, and again on the surface of the alluvium of the eastern part of the coalfield. Resulting apparently from the gradual evaporation of carbonate solutions, which are brought to the surface by capillarity, this formation of kankar still continues at the present

[1] A Manual of the Geology of India, Pt. 3, p. 371, (1879).
[2] *Rec. Geol. Surv. Ind.*, X, p. 151, (1877).
[3] *Mem. Geol. Surv. Ind.*, III. p. 195, (1861).

time. Its utility as a flux has been discussed by Mr. Hughes,[1] from whose description the following analyses are taken:—

	Barmuri.	Ramnagar.	Sanktoria.
	Per cent.	Per cent.	Per cent.
Insoluble	40·6	30·4	27·2
(Silica)	(32·8)	(23·0)	(19·4)
Oxide of iron and aluminium	2·7	1·9	2·0
Carbonate of lime	54·0	65·4	66·3
Water and organic matter	2·7	2·3	4·5

Analyses by Mr. Tween.
Specimen from Basera yielded 79·5 per cent. Ca Co_3.

	Raniganj.	Raniganj.	Raniganj.	Barakar.	Bhiokund.
Carbonate of lime	72·0	56·94	66·50	66·20	78·50
Carbonate of magnesia	1·30	1·72	0·20	1·50	2·00
Oxide of Fe.	0·70	1·67	3·20	2·80	2·00
Clay	22·0	30·0	27·60	22·00	10·50
Sand (free)	2·0	9·67	2·50	7·50	7·00
TOTAL	98·00	100·00	100·00	100·00	100·00

Analyses by Mr. Dejoux.

Use as a flux.

Although kankar was apparently used successfully in the Birbhum Iron works in 1860, that of the Raniganj field was found to be too irregular in composition to be of any permanent importance as a flux in the Barakar furnaces, and it is improbable that these deposits will ever prove to be of value in the future manufacture of iron. The total quantity available is comparatively large, but its scattered occurrence and inconstant quality will, doubtless, render its use impracticable.

At present it is used by a number of small lime-burning concerns within the coalfield, the lime being utilised locally for building purposes.

(ii) Building-stone.

The massive sandstones of the Barakar measures provide very useful building material within the Raniganj field, whilst the harder rocks of the Raniganj and Talchir series are also of serviceable

[1] *Rec. Geol. Surv. Ind.*, VII, pp. 25-26, and p. 123, (1874).

quality. These sandstones have been used to some extent in the construction of the various bridges and culverts within the area, and in less degree, for the construction of buildings, shaft-linings, and as machinery-foundations. The excellence of the stone of the upper Barakar measures, near Begunia, is exemplified in the Grand Trunk road bridge that spans the Barakar river, whilst similar stone, from which the Jain temples of that vicinity have been built, has stood the wear of considerable time. A portion of the new High Court in Calcutta is reported to have been built of sandstone from Barakar. These sandstones, and in addition the harder Talchir types, are also quarried as mill-stones, whilst the softer Talchir sandstones are, in some cases, carved into drinking-troughs and similar utensils.

Begunia sandstones.

(iii) Road-metal.

Road-metal is largely derived either from the doleritic dyke-outcrops within the coalfield or from the reefs of white quartz that intersect the metamorphics outside the limits of the area. In the eastern part of the field, however, the roads are to a large extent paved with rubble laterite, which hardens to form an excellent even surface.

Ballast for the railways is also obtained from the dolerite and quartzite outcrops, but in addition, the mica-peridotite sill-exposures and the indurated Barakar sandstones with which they are associated, are also quarried superficially in the northern parts of the coalfield.

APPENDIX.

HISTORY AND DEVELOPMENT OF THE COALFIELD.

A concise account of the early history of colliery development within the Raniganj field and of the condition of the industry at the time of his survey during the years 1858 to 1860, has been given by Dr. Blanford.[1] From this report certain extracts, given below, have been quoted. This account was briefly added to by Mr. Walker in 1913,[2] whilst further details may be gleaned from the annual reports of the Chief Inspector of Mines.

Sumner, Heatly and Redferne, 1774 to 1777.

In the opening chapter of this memoir, reference has been made to the earliest attempt on record of the systematic working of coal in India by Messrs. Sumner, Heatly and Redferne in 1774. Having obtained the right of raising coal over a large area within the middle-western portion of the field, these early pioneers are reported to have opened mines at Aitura, Chinakuri and Damulia. As has been indicated by Dr. Fox,[3] 'Aitura' was probably the old name applied to the village of Ethora, and it is suggested that the mine indicated is represented in certain of the old outcrop workings of the Dishergarh seam between Sitarampur and Ethora villages. At Chinakuri, the outcrop of one of the middle Raniganj seams was doubtless worked, whilst in the case of Damulia (Damalia), the mine referred to is now probably represented by one of the abandoned quarries into the Raniganj seam, which crops out beneath the alluvial gravels of that area.

It was agreed that one-fifth of the produce be paid to Government, and that 10,000 maunds of coal per annum would be supplied over a period of five years at Rs. 2-12 per maund. In 1775 Messrs. Sumner & Co., announced to Government the arrival of 2,500 maunds of 'Panchet coal' and requested that it might be received. Such does not, however, appear to have been done until 1777 when, a fresh application having been made, Government directed the Commissary of Stores to report upon the coal. From experiments, the latter concluded that it was only half as good as English coal, and it was consequently returned to the firm with an intimation from Government, that they would still give every assistance to the miners in endeavouring to produce coal of better quality, for which they recommended further search and deeper excavation. It is stated that Mr. Heatly procured English miners and made preparations for working the coal upon a large scale. Fever, however, carried off most of the men and Mr. Heatly himself was removed to a different part of the country. It is doubtful whether any of the coal that was mined was ever brought into the market.

Jones, 1814.

No further attempt was made to exploit coal within the Raniganj field for nearly 40 years, until in 1814, Mr. Jones was deputed by Government to examine the area. In the following year, having received an advance of Rs. 40,000 from the public treasury, Mr. Jones opened

[1] *Mem. Geol. Surv. Ind.*, III, pp. 154-178, (1861).
[2] *Trans. Min. Geol. Inst. Ind.*, VII, pp. 268-271, (1913).
[3] *Op. cit.*, XXIV, p. 98, (1929).

the mine near Egara and brought coal into the Bengal market. For reasons unknown, he failed in making the enterprise a financial success and in 1820 the colliery was taken over by Messrs. Alexander & Co., who had stood security for him. Quoting from Dr. Blanford[1] :—

Frequent disputes.

'The history of the Raniganj field from that period is the history of one continued succession of fightings and litigations. The constant endeavours of Messrs. Alexander & Co., and their successors, was, not unnaturally, to obtain a monopoly of the valuable coal district around them, and to prevent any one else from establishing himself in it. For every mine it was necessary to have, not merely a lease or pottah of the land on which the coal was procured, but also of a ghât or shipping place from which the coal could be sent by the river to Calcutta and permission to make a road to connect the two. Labour was also necessary, and, for the purpose of obtaining command of it, it was, and still is (in 1860), customary to procure from the proprietors leases of villages. On all these points, amongst a race of litigants, and with the peculiar facilities afforded by the law and customs of the country for the promotion of legal disputes, it would be strange if questions as to right of ownership, right of way, and rights of every sort and kind, should not constantly be arising : and they did arise most abundantly. When endless law suits were the price at which alone it was possible for any one to commence mines in the Raniganj district, it is not surprising that the greater number of speculators would be discouraged, and that the longest purse would, in the end, have all the advantage. But even if the real facts could be ascertained, no information of value would be gained from a detail of the petty squabbles of the various coal owners, although, on the whole, they have had a most important effect in impeding the progress of the district. Divested of unimportant circumstances, the following is a brief summary of the order in which various mines were commenced.'

Chinakuri, 1823-24.
Damulia, 1824.
Narrainkuri, 1830.
Salunchi, 1831-32.

'In 1823, or the commencement of 1824, Chinakuri colliery was opened by Mr. Betts, probably upon the spot where had formerly been Mr. Heatly's works. Damulia was, about the same time, or a few months later, in 1824, re-opened by Messrs. Jessop & Co., but they lost it sometime afterwards by a law-suit, and opened at Narrainkuri in 1830. The Salunchi seam (near Chinakuri) was first worked a year or two after, and the old mine at Chinakuri was abandoned at the same time, or soon after about 1836.'

Chanch and Nuchibad, 1830.
Chokidanga, Dhosul, 1834.

'The quarries at Chanch and Nuchibad[2] were also commenced about 1830, or within a few years subsequently by Mr. Homfray, of the firm of Jessop & Co. Chokidanga, Mamadpur, was opened by Dr. Rogers in 1834, and Dhosul by Mr. Blake about the same time.'

Carr, Tagore & Co., 1885.

'Within a few years from this time several of the principal collieries then existing passed into the hands of other proprietors. One thousand eight hundred and thirty-five was a bad commercial year, and many large agency houses failed, among them Messrs. Alexander & Co. Raniganj mine was purchased by Babu Dwarkanath Tagore, and subsequently worked by the

[1] *Mem. Geol. Surv. Ind.*, III, p. 157, (1861).
[2] *Nuchibad* probably refers to Luhchibad.

firm of Carr, Tagore & Co. It is said that, so much was the value of such property depreciated at the time of the sale, that the whole estate, including several valuable *patni* and other tenures, together with all the buildings, and works, steam engines, etc., on the mine, nearly 250,000 maunds of coal[1] at market, and a large quantity more at the mine, together with all advances made to boatmen, was sold for 70,000 Rupees: less than the value of the coal at market alone.'

Gilmore, Homfray & Co., 1837.

'In 1837 Narrainkuri, Chanch, and Nuchibad passed into the hands of Messrs. Gilmore, Homfray & Co., and in the same year Chinakuri was purchased from Mr. Betts, Junior, by Messrs. Carr, Tagore & Co.'

Mangalpur, 1840.

'Mangalpur and Rogonathchuk were opened in 1840 by Mr. Erskine. About this time, or a little earlier, quarries were worked by Messrs. Carr, Tagore & Co., at Dezira-garh[2], Hirakund, and Narrainpur (or Nodiha), while others were carried on by natives at Barmuri, Beldanga near Raniganj, Kantagoria (now Bhangaband), and some other places.'

Bengal Coal Company, 1843.

'In 1843 the concerns of Messrs. Carr, Tagore & Co., and Messrs. Gilmore, Homfray & Co., were amalgamated into the Bengal Coal Company, who abandoned Narrainkuri, and for the time, almost all their mines, except Chinakuri and Raniganj, the old mine at the latter place having been destroyed by fire in 1842. A new mine, however, was at work before the loss of the old one. This Company has existed ever since, and has now, by far, the most extensive collieries of any proprietors in the field.'

1840-1847, great increase of workings.

'From 1840 to 1847, during which period Mr. William's survey took place (1845-46); and the final report of the Coal Committee was issued (1845), there was a constant and large increase in the quantity of coal mined. According to Mr. Homfray, the number of maunds imported into Calcutta from Raniganj was, in 1839, 10,00,000; in 1846, 25,00,000. The Coal Committee give 17,00,000 as the probable consumption in 1845 and 12,00,000 for the average of the four previous years. Mr. Homfray's figures give respectively 20,50,000 and 16,30,000. Several new mines were opened; among them Siarsol, by Babu Gobind Parsah Pundit; Nimcha, Sangamahal, Gopinathpur, and Kasta, by Messrs. Grob, Durrschmidt & Co.; Sitarampur, by Messrs. Apear & Co.; Kumar-dubhi and some other mines, by the Indian Coal, Coke, and Mining Company.'

Continued progress since 1847. Railroad opened.

'There has been, on the whole, a steady progress since that time, both in the number of collieries worked, and in the total quantity of coal produced. The latter, especially, has increased to a great extent since the railway has afforded increased facilities for transmission to a market. This has produced an important change in two ways: *First*, by greatly stimulating mines in its own immediate vicinity, that is, in the neighbourhood of Raniganj; and, *secondly*, by rendering possession of the ghâts unnecessary while the roads are easier of access than the river. Its own requirements also have very materially increased the demand for fuel.'

1858 to 1860.

At the time of Dr. Blanford's survey, nearly 50 collieries had been established, yielding an average production, over the three years 1858 to 1860, of 78,08,566 maunds, or 281,994 tons of coal.

[1] Above 9,000 tons.
[2] *Deziragarh* doubtless refers to Dishergarh.

River transport.

Previous to the construction of the railway, the coal was shipped into boats from 'ghâts' located at Narrainkuri (*see* Plate 1), Damalia and Chinakuri. Since certain stretches of the Damodar river were navigable only during periods of flood, the journey to Calcutta often took several months, whilst in many cases the boats were lost. In addition to this slow and uncertain method of transport, the coal doubtless disintegrated and deteriorated in quality during the lengthy period of shipment.

Extension of the railway.

Early in 1855, the East Indian Railway was opened as far as Raniganj, and as a result, the production of the mines of that locality increased rapidly. Some ten years later, the line reached to Barakar and was continued north-westwards from Sitarampur Junction to link up with the railways of the Gangetic plain.

Oldham, 1868.

Writing in 1868, Dr. Oldham[1] observed that the requirements for several years before 1860 were largely for the East Indian Railway construction.

Subsequently he continues :—

'although the demand for works of construction diminished, the line of railway itself was gradually opened up and the extension of communications led to greater demands for fuel. These demands have continued to increase at a rapid rate, until in 1866, in consequence of the extension of the use of coal instead of wood to the upper sections of the line (the completion of the Jumna bridge at Allahabad enabling this to be carried out) the demand of the previous year was nearly doubled.'

Output in 1868.

In 1868, the following five principal companies held sway in the Raniganj field and produced the greater proportion of the total output of coal :—

	Maunds.
Bengal Coal Co.	61,39,105
Gobind Pundit, Sirsole (Siarsol)	24,28,428
Beerbhoom Co.	13,62,635
Equitable Coal Co.	11,60,292
East Indian Coal Co.	8,30,605

giving a total outturn from these five companies of 1,19,21,065 *maunds* out of a total of 1,34,50,829 *maunds.*

Referring to the condition of the Raniganj coal-industry in 1876, Mr. F. J. Agabeg observes[2] :—

'Dishergarh had just commenced operations, Sanctoria was in its youth, and the output of Sodepur was small. The Equitable Coal Co., at Barmondiah (Barmundih), were working a few quarries and shallow pits in the Dishergarh seam. At Luchipur, quarry work was in full swing; Belrui, belonging to the Beerbhoom Coal Co., was also working with shallow pits. Still further on we come to Sitarampur where the seam now known as the Dishergarh, but then named the Sitarampur, was being mined by Apcar & Co., who were the first to sink shafts in it. This firm also had collieries at Raghunathbatty, Ramjibanpur, Borachuck, Fatehpur,

[1] *Mem. Geol. Surv. Ind.*, VII, p. 135, (1871).
[2] *Trans. Min. Geol. Inst. Ind.*, IX, Pt. 1 (1914).

Narsamuda and Gopalpur. Further east we come to Dhadka, worked by the Beerbhoom Coal Co. To the northeast of the field the only two concerns operating were Apcar & Co., and Shib Kisto Daw & Co., at Charanpur and Sibpur respectively. At Barakar, the Bengal Coal Co., were working Chanch and Laikdih, and the Barakar Coal Co., Kumhardubhi. Apcar & Co., had also been working coal at Kasta beyond the Adjai river. Raniganj was the headquarters of the Bengal Coal Co., and most of their output came from pits in that neighbourhood. The Raniganj Coal Association were developing the Toposi area. From Raniganj to Asansol, except at Nimcha and Siarsol there were no collieries to be seen.'

Early workings at the outcrops.

The old method of working was almost invariably from inclines or quarries located at or near the outcrop, and at the time of Dr. Blanford's survey few pits existed of a greater depth than 100 feet. Such open and incline-workings were extended as new coal seams were discovered, but as the years advanced, the number of pits of a depth of several hundred feet increased.

Continued progress.

Progress continued at a rapid rate; the Gourangdi area was opened up by the Barakar Coal Co., and in the early years of the present century a number of companies were floated to work the upper seams of Raniganj stage within the Kalipahari-Ghoshik and Satpukhuriya localities. In addition, the opening of the Andal-Sainthia branch of the East Indian Railway in the beginning of 1907, raised greater interest in the eastern part of the field.

1914 to 1919 boom.

At the time of Mr. Walker's survey, however, most of the pits reached to only a comparatively shallow depth, usually not more than 600 feet, though shafts of about 900 feet were being sunk at Sodepur. Again, during the period of the Great War, and the year which followed, the demand for coal of all qualities was high and speculation ran rife. A large number of new collieries were established among which were many of those of the eastern portion of the coalfield; and numerous incline-workings were commenced in seams previously regarded as of too inferior a quality to be of economic value. Following this boom period, the depression of 1920 to 1921 resulted in the closing down of many of the collieries working coal of inferior grade, and brought the general progress of colliery development almost to a standstill. The larger companies of long-standing, and the more recent concerns working the more valuable seams, continued to carry on, though the total output of the field fell in one year (1920) by more than 1,800,000 tons.

1920 to 1921 depression.

Recent progress.

The year 1921, however, saw the completion of the deep shafts into the Dishergarh seam at Parbeliya colliery. These two shafts are of a depth of about 1,480 feet—the deepest in India. More recently, in 1927-28, the 1,300 foot shafts of Ningah colliery were completed down to the Poniati seam. In the year 1922, the Kasta branch of the East Indian Railway was opened and gave additional facilities to the collieries of the Trans-Adjai area. During more recent years, comparatively steady progress has again set in though the total annual output of the field (1929-30) still falls short of the maximum figure (6,815,126 tons) of the year 1919, by over a quarter of a million tons.

As the progress of railway-communications and colliery development continued, it was to be expected that other industries would spring up within the coalfield. These include the following brickworks, engineering works, &c., for the details of which the writer is indebted to the Managers of the various concerns.

1. Brick and pottery works.

(a) *Raniganj Pottery works, &c.,* (*Messrs. Burn & Co.*) *see Plate 18.*

The original works on the north side of the railway at Raniganj, were first opened about 1859, and have since developed into a large modern establishment in which sanitary stoneware pipes and fittings, and refractory materials are made. The kilns in use are some 60 in number and range from 20 to 30 feet in diameter. On the opposite side of the railway, the Lal Koti silica works are situated. Started in 1918, these works are devoted solely to the manufacture of silica products suitable for the lining of steel-manufacturing plants, coke-ovens, &c. The kilns, ten in number, and ranging from 20 to 26 feet in diameter, are capable of a production of about 1,000 tons a month.

Other works belonging to the same company include the firebrick works at Garphalbari and the tile and brick works at Durgapur. The former, started in 1910, have a capacity of 2,000 tons monthly. At Durgapur, where operations were first commenced in 1900 and modernised in 1918, red roofing tiles of Raneegunge pattern lock type are manufactured. The output is about 8,000 tiles per day, though the works are designed for a daily production of 25,000. Red bricks are also manufactured. Two continuous coal-fired kilns of the company's own design are in use.

(b) *Kumhardubhi Fireclay & Silica works.*[1] (*Messrs. Bird & Co.*) *see Plate 19.*

These works were constructed at Kumhardubhi for the production of silica bricks, firebricks, and stoneware.

The silica department includes 10 beehive coal-fired kilns of down-draught type, each with a capacity of half a *lakh* of bricks. The total production is about 15,000 tons of silica bricks per year. Within the fireclay department, firebricks of a high quality, suitable for all classes of refractory work, are manufactured. Standard bricks are made by machinery at the rate of 12,000 per day. The kilns comprise:—

(i) Regenerative, gas-fired, continuous kiln of 10 chambers, capable of producing 10,000 bricks per day.

(ii) A battery of eight beehive, down-draught, coal-fired kilns, each holding 25,000 bricks.

The stoneware department is capable of producing salt-glazed pipes from 4 to 24 inches in diameter, moulded by machinery, and baked in five kilns of beehive pattern.

(c) *Reliance Firebrick works.* (*Messrs. Andrew Yule & Co.*).

Situated at Chanch, the construction of these works was commenced late in 1917 and completed early in 1920. They include 16 down-draught circular kilns,

[1] See also *Trans. Min. Geol. Inst. Ind.*, XVIII, p. 102, (1924).

with a full capacity of approximately eight *lakhs* of standard bricks or their equivalent per month. The products include all types of refractory materials for iron and steel plants, and other types of furnaces.

(*d*) *Bengal Firebrick works.* (*Messrs. Martin & Co.*).

Situated at Kulti, adjacent to the Bengal Iron Company's works, these works came into existence in 1919, primarily to supply the Iron works with firebricks for the lining of furnaces, cupolas, coke ovens, etc. There are nine kilns of the circular down-draught type some of which burn 60,000 firebricks each, of various shapes and sizes, monthly. The class of firebricks manufactured is of excellent quality such as is required in lining blast furnaces. Another class of firebrick, containing a large percentage of alumina, is made for lining rotary kilns used in the manufacture of cement, and these have been reported by the users, as superior to the bricks imported for this purpose.

In addition to firebricks, the works turn out excellent stoneware pipes from four to nine inches internal diameter. They also manufacture blue bricks, which are equal to those made in Staffordshire, and which are used in the facing of the walls at King George's dock and the new lock entrance, at Calcutta.

(*e*) *Behar Firebricks & Potteries, Ltd.*, (*Messrs. A. C. Banerjee & Co*).

Situated near Mugma station, these works were constructed in 1920 for the production of firebricks and flat roofing tiles. The works include eight down-draught kilns of 20 to 24 feet internal diameter, capable of producing 500,000 firebricks, of standard type, monthly. The present production is reported to be 200,000 firebricks, size 9 by 4½ by 3 inches, or their equivalent in other sizes.

2. Iron and engineering works.

(*a*) *Bengal Iron Co.'s works.* (*Messrs. Martin & Co.*)[1] *see Plate 16.*

These works, which now include the Kulti blast furnaces, coking plant, and foundry for castings, were originally commenced as an experiment by Messrs. Jessop & Co., near Barakar in 1839. Later on, ironworks were erected at Kulti and were privately operated as the 'Barakar Iron works' until about 1879, when Government supported the establishment for nearly 10 years. In 1889, these works were taken over by the present managing agents and the plant was completely remodelled. The new company was called 'The Bengal Iron & Steel Co., Ltd,'. though in 1919, this title was changed to the present form—'The Bengal Iron Co., Ltd.'. The Kulti works include five blast furnaces, and until the post-war depression set in, most of these were in operation. Ferro-manganese was also manufactured. During the period 1925 to 1927, the furnaces were largely closed down, but several have more recently been remodelled and the production of pig-iron recommenced. The coke ovens include four batteries each of 34 ovens, all of Messrs. Simon Carves regenerative type, with an output, in 1924, of 23,000 tons per month. Tar and ammonia are recovered from the waste gases, the necessary sulphuric acid for the direct recovery of ammonia being made at the company's works.

[1] For further details, see Quinquennial Review of the Mineral Production of India for the years 1919 to 1923. *Rec. Geol. Surv. Ind.*, LVII, (1925).

(*b*) *Indian Iron & Steel Co.'s works.* (*Messrs. Burn & Co.*)[1] *see Plate 17.*

These iron-works include the blast furnaces and coking plant at Hirapur (Burnpore). The company was floated in 1918. The works include two 350-ton, mechanically charged, modern furnaces for the production of pig-iron. The coke oven and by-product plant consists of two batteries, each of 80 Simon-Carves, horizontal flue, waste-heat ovens capable of producing 1,000 tons of coke per day. The direct recovery system is employed for the recovery of by-products, and a sulphuric acid plant, capable of producing 18 tons of 80 per cent. acid per day from natural sulphur, has been installed.

(*c*) *Eagle Iron works.* (*Messrs. Bird & Co.*).

These works, which commenced operations at Kumhardubhi in the year 1925, include four coal-fired re-heating furnaces of a type commonly used on the Continent. Carefully selected scrap iron is fagotted and re-rolled into merchant bars, eminently suitable for Indian bazaar trade, such as cart tyres, cart axles, window-frames, Persian wheel manufacture, plough points, &c.

(*d*) *Kumhardubhi Engineering works.*[2] (*Messrs. Bird & Co.*).

Also situated at Kumhardubhi, these works were originally the old repair shops of the Burrakar Coal Co., and were floated as a limited company in 1915 and afterwards extended very considerably. The foundry, fitting, and machine shops have now been developed into well-equipped establishments with machines, cupolas and crucible furnaces, &c., of modern design, capable of handling any type of work, including bridge-construction, both in the colliery area, and in more distant parts of India.

(*e*) *Indian Standard Wagon Co., Ltd.* (*Messrs. Burn & Co.*).

Located near the iron-furnaces at Hirapur (Burnpore), this company was founded in 1919 and commenced production in 1921. Aided by a Government bounty for two years, the works are, at present, capable of an outturn of 3,000 broad gauge, open railway wagons per year, but could, with a small expenditure on improved tools, bring this figure up to 4,000. Mass-production methods by machinery have now largely been adopted. Everything required for wagon building, with the exception of the wheels, which are supplied by the railways themselves, is manufactured. The works also include a spring shop capable of producing springs both for the railway and for general engineering purposes in India.

(*f*) *East Indian railway workshops at Andal.*

(*g*) *Paper mills,* (*Messrs. Balmer, Lawrie & Co.*) *situated at Ballavpur, near Raniganj.*

In addition to the above-mentioned establishments, a number of the larger collieries possess workshops capable of handling all the small repairs that arise during the course of mining development.

[1] See Quinquennial Review of the Mineral Production of India 1919 to 1923. *Rec. Geol. Surv. Ind.*, LVII, (1925).
[2] *Trans. Min. Geol. Inst. Ind.*, XVIII, p. 99, (1924).

Foundry at Sarshatali.

Within recent years, a large foundry was constructed at Sarshatali with the object of manufacturing textile machinery, but has subsequently been closed down and dismantled.

DEVELOPMENT OF THE MINING INDUSTRY.

Early methods of mining.

The habit of exploiting the seams at their outcrops by means of incline or quarry-workings, was in general practice during the early days of mining within the Raniganj field, and in a number of instances this method of extraction continues at the present day. This mode of working was commented on adversely by Dr. Blanford, and has more recently drawn the fire of a number of mining authorities acquainted with the coalfield. The practice, combined in the old days with a complete disregard for the importance of barriers, has doubtless resulted in the loss of large areas of many of the seams at and near their outcrops, as a result of fires and flooding. A further loss has been entailed owing to the absence of plans of many of these incline and shallow pit-workings, as a result of which more recent collieries, exploiting the seams from shafts located further to the dip, have been forced to leave barriers of unknown width in order to avert the danger of tapping these flooded outcrop-workings.

'Pillar and stall' system.

The earliest method of working underground was the 'pillar and stall' system, and this mode of extraction prevails in almost all the collieries at the present day. In the early days of mining the pillars were small, ranging according to Dr. Blanford, from 12 to 18 feet square, the galleries being almost as wide as the pillars. By this system of working, allowing the most favourable circumstances, not more than two-thirds of the coal could be extracted, and in the case of the thicker seams, considerably less. In many instances, however, the crushing of such small-sized pillars occurred long before the mine had reached its maximum development, and resulted in underground fires, an influx of water from the surface, and the abandonment of large areas of valuable coal both within and around the limits of the workings. With the advance of mining, however, the size of the pillars was increased and at the present day varies normally from 80 to 100 feet in width, the galleries being of a maximum width of 15 feet, whilst the practice of leaving barriers of coal at suitable intervals reduces the possibility of large areas of coal being lost as a result of fire or flooding.

'Long-wall' system.

The 'long-wall' system of working was employed in the early days by Messrs. Apcar & Co., in the case of the Raghunathbati seam, near Sitarampur, and has more recently been adopted at Narsamuda colliery and to some extent at Saltor.

The primitive method of de-watering the workings by means of the *teruh*[1] has disappeared and up-to-date pumping plants are now installed at all the larger collieries. For the purpose of raising the coal from the pits, the old-fashioned 'gin' has fallen into complete disuse; and only in one instance, at a small colliery near Barabani, were women employed for this purpose (*see* Plate 12). In certain

[1] A long horizontal pole or bamboo, working on the top of two vertical poles, and having a bucket, or an earthen pot, attached to its longer end by a vertical bamboo, while its shorter end, bearing a stone or a mass of mud as a counterpoise, is hauled down by ropes. (Blanford).

of the smaller incline-workings, however, the use of manual labour for the purpose of conveying the coal to the surface, is by no means exceptional. At all the more important collieries, however, modern headgears and haulage-ways exist.

Electrification.

Advances in other directions include the electrification of many of the larger collieries. In this connection, the Dishergarh Power Supply Co.'s Central Power station at Sodepur, completed in 1922, is the largest of its type, and distributes current to a number of collieries adjoining the Damodar and Barakar rivers. In the case of certain of the more important collieries, coal-cutting machines are in use, and efficient screening plants and mechanical ventilators have been installed. Safety-lamps are also used in mines where firedamp is prevalent.

Sandstowing.

Sandstowing has been practised, at least to a limited extent, at several collieries, including Ramnagar, Seetalpur, Parbeliya, and Saltor. These collieries are all situated in the near vicinity of the Damodar or the Barakar rivers, from the bed of which the sand is obtained. During recent years, however, owing to the general depression of the coal-trade, this practice has, in some degree, fallen into disuse. At Saltor colliery, the sand is taken from the Damodar river by a mechanical ' grab ', transported along an aerial ropeway to a wide diameter bore-hole located on the mainland near the river bank, and from there is fed into the underground workings (*see* Plate 13, Fig. 2). A second aerial ropeway spans the Damodar river from Saltor island to the mainland, and is used for transporting the coal of the island colliery to the depôt, where it is fed on to a screen, which conveys and loads it directly into the railway wagons. In 1928, a sandstowing plant was installed at Sodepur colliery. The sand, loaded from the Damodar river into tubs, is conveyed up a short haulage-way into a large bin from which it is discharged into buckets and transported along an aerial ropeway to the vicinity of the colliery. From the buckets, it is automatically tipped into a second bin, which links up with the underground workings by means of a vertical borehole of wide diameter.

Labour.

With the enormous development of the mining and allied industries, a demand for labour has been created far in excess of the indigenous population of the district. Much has been done to encourage the miner to settle near the collieries, whilst in other cases, batches of workmen are recruited from more distant districts and remain at the collieries for periods of a few months at a time. Much of the labour is, however, still of a very transitory character and during the periods of planting and harvesting their crops, there is a general exodus to the villages. Regarding the question of health, comfort and education of the worker, considerable advances have been made, though much still remains to be done. The problem is a difficult one, and as a result of the natural primitive up-bringing of the majority of the miners, progress is necessarily slow. In this connection the establishment of the Mines Board of Health, Asansol, has done much useful work.

Education.

For those more advanced workers who wish to extend their technical knowledge of mining and to sit for the *sirdar's* certificate examination, courses of lectures are given in Hindi at various convenient centres within the field. In 1906, a scheme for courses of lectures was commenced to enable mining officials of the superior grades to obtain the necessary technical training to qualify for certificates of competency as mine managers; whilst the opening of the Indian

School of Mines at Dhanbad, in November 1926, has further enhanced the opportunities of candidates seeking employment in the various departments of the mining industry.

Department of Mines.

The Raniganj coalfield is included in No. 2 Circle of the Department of Mines. Within the annual reports of the Chief Inspector of this department, references to the modes of working, questions of labour, output of coal, &c., &c., are to be found.

Future development.

Even a casual inspection of the field could not fail to make one realise the very considerable advances that have been made in coal-mining within this area during the past century. Extensive flooded quarry or incline-workings, with their attendant derelict buildings and machinery, bear witness to the injurious and wasteful methods of winning the coal in the early days. Alongside, we find up-to-date shafts, well-equipped with modern mining appliances and run under capable management and supervision. That the future will see the establishment of deeper shafts down to at least the more important coal seams, is certain. The present Chief Inspector of Mines has recently attempted to force home the question of sand-stowing within the Jharia field,[1] in order that the good quality coals of that area may be worked to the ultimate maximum advantage of the coal and allied industries of India. That large deposits of coal of superior quality exist also within the Raniganj field is undoubted, whilst in the Damodar, Barakar and Adjai rivers are enormous deposits of sand, located, in many cases, within easy reach of the collieries. To what extent this fortunate combination of circumstances will be made use of in the case of the Raniganj coal industry, so that the coal may be won at a minimum loss, only the future can reveal.

[1] *Trans. Min. Geol. Inst. Ind.*, XXIV, pp. 110-114, (1929).

BIBLIOGRAPHY.

HEATLY, S. G. T. AND SUMNER, J. — *Journ. Asiat. Soc., Bengal,* XI, No. 1, pp. 813-814, (1842). Earliest attempt at working coal in the Raniganj field, 1774.

MOTTE AND FARQUHAR — *Supra,* p. 822. Proposal to Government for permission to work the iron-ore deposits of the Raniganj field, 1777.

HERBERT, J. H. . . 'Notice on the occurrence of coal within the Indo-Gangetic tract of mountains.' *Asiatic Researches,* XVI, pp. 397-402, (1828).

JONES, R. . . 'Description of the Northwest Coal District, stretching along the river Damoodah from the neighbourhood of Jerria or Juriagerh to below Sanampur in the Pergunnah of Sheargerh, forming a line of about 65 miles.' *Asiatic Researches,* XVIII, Pt. 1, p. 163, (1829).

EVEREST, REV. R. . 'Geological observations made on a journey from Calcutta to Ghazipur.' *Gleanings of Science,* III, p. 129, (1831).

DE LA BECHE . Geological Manual, p. 399, (3rd edn., 1833).

Report of the Coal Committee, 1838. First report of committee for investigating the coal and mineral resources of India.

FORBES ROYLE, DR. . 'Illustrations of the Botany, etc., of the Himalayan Mountains', p. 29, (1839).

HOMFRAY, J. . . 'A description of the coalfield of the Damuda Valley and the adjacent countries of Bheerbhoom and Poorooleah, as applicable to the present date 1842.' *Journ. Asiat. Soc., Bengal,* XI, pp. 723-739.

" . . 'The Damuda Valley or Raniganj coalfield', pamp. 8°, Calcutta, (1847).

" . . *Journ. Asiat. Soc., Bengal,* XVII, Pt. 2, p. 703, (1848). Notice of ball coal from Seeterampore colliery.

MORNAY . . . 'Notice on three Trap Dykes in the Burdwan district, etc.', *Cal. Journ. Nat. H ist* II, Pt. 2, p. 126, (1842).

ROBINSON, S. H. . . *Cal. Journ. Nat. Hist.*, III, p. 418, (1843). Section of coal measures at Chowkeedanga colliery, Burdwan District.

Report of Coal Committee, 1845.

PIDDINGTON, H. . . *Journ. Asiat. Soc., Bengal,* XVII, p. 59, (1848).

" . . *Op. cit.*, XVIII, p. 412, (1849).

" . . *Op. cit.*, XIX, p. 75, (1850).

" . . *Op. cit.*, XX, p. 365, (1852).

" . . *Op. cit.*, XXI, pp. 270-274, (1852).

" . . *Op. cit.*, XXV, p. 365, (1857).

References to 'ball' coal and analyses of coals of the Raniganj field, etc.

WILLIAMS, D. H. . Geological Surveyor in the service of the East India Company. 'A Geological Report on the Damoodah Valley.' Printed in London by order of the Court of Directors, 1850. Reprinted in Calcutta, 1853.

HOOKER, DR. J. . . 'Himalayan Journals', I, p. 7, (1855).

SMITH, DAVID . . 'Report to the Government of India on the Coal and Iron Districts of Bengal.' 2nd July, 1856. *Sel. Rec. Govt. India,* LXIV, pp. 74-90.

OLDHAM, DR. T. . . 'Geological Relations and probable Age of the several systems of rocks in Central India and Bengal.' *Mem. Geol. Surv. Ind.*, II, pp. 299-335, (1860).

" " . . 'Additional remarks on the Geological Relations and probable age, etc., etc.', *Op. cit.*, III, p. 197, (1861).

" " . . 'Mineral Statistics,—Coal.' *Ibid.*, III, Art, II, pp. 1-12, (1861).

" " . . 'Memorandum on the Coal Resources and Production of India', *Sel. Rec. Govt. Ind.*, LXIV, pp. 40-156, (1868).

" " . . 'Mineral Statistics—Coal', *Mem. Geol. Surv. Ind.*, VII, Pt. 2, pp. 131-150, (1871).

BLANFORD, W. T. . 'On the Geological Structure and Relations of the Raniganj Coal-field, Bengal.' *Op. cit.*, III, Art. I, (1861).

,, ,, . 'On the rocks of the Damuda group, and their associates in Eastern and Central India, as illustrated by the re-examination of the Raniganj field.' *Journ. Asiat. Soc. Bengal*, XXIX, pp. 352-358, (1860).
Pal. Indica, Series IV, Vol. I, Pt. 1, (1865). Reprinted 1888.

HUGHES, T. W. H. . 'The Jheria coal-field.' *Mem. Geol. Surv. Ind.*, V, Pt. 3, (1866).

,, ,, . 'Raw materials for iron-smelting in Raniganj field.' *Rec. Geol. Surv. Ind.*, VII, pp. 20-30, (1874).

,, ,, . 'Second note on raw materials, etc., etc.', *Op. cit.*, VII, pp. 122-124.

HUGHES, T. W. H. AND MEDLICOTT, H. B. 'Trials of Raniganj Fire-bricks.' *Rec. Geol. Surv. Ind.*, VIII, pp. 18-20, (1875).

BAUERMAN, H. . . 'Report on the Iron-ores of India.' *Gazette of India, Suppl.*, pp. 1457-59, 1494-96.

MEDLICOTT, H. B. . Annual Report, *Rec. Geol. Surv. Ind.*, VII, pp. 1-11, (1873).

MEDLICOTT, H. B. AND BLANFORD, W. T. 'A Manual of the Geology of India.' 2nd edn. (1893) revised by R. D. Oldham.

BALL, V. . . . . 'On the Atgarh Sandstones, near Cuttack.' *Rec. Geol. Surv. Ind.*, X, pp. 63-68, (1877).

,, ... 'Geology of the Rajmahal Hills.' *Mem. Geol. Surv. Ind.*, XIII, Pt. 2, 1877.

,, ... Manual of the Geology of India, III, Economic Geology, (1881).

MALLET, F. R. . . 'Limestones in the neighbourhood of Barakar.' *Rec. Geol. Surv. Ind.*, X, pp. 148-152, (1877).

TWEEN, A. . . . *Op. cit.*, X, pp. 155-158, Analyses of Raniganj coals.

FEISTMANTEL, O. . . 'The Fossil Flora of the Gondwana System.' *Pal. Ind.*, Series XII, Vol. III, Pt. 2, (1880) and Vol. IV, Pt. 2, (1886).

RUTLEY, F. . . *Trans. North. Eng. Inst. Min. & Mech. Eng.*, XXX, p. 13, (1880). Ultra-basic intrusives of the Raniganj and associated Damodar Valley coal fields.

BOSE, P. N. . . 'Mica Traps from Barakar and Raniganj.' *Rec. Geol. Surv. Ind.*, XXI, pp. 163-165, (1888).

Chief Inspector of Mines in India. *Annual Reports*, 1895 to date.

Director, Geological Survey of India. Annual and Quinquennial Reviews of the Mineral Productions of India, *Records, Geol. Surv. Ind.*, 1898 to date.

DUNSTAN, PROF. W. R. 'Coal Resources of India and their development.' Ind. Agric. Ledger, No. 14, 1898.

" " *Technical Reports and Scientific Papers*, Imperial Inst., 1903.

" " *Flying Seal Series*, No. 364, Imperial Institute, London, 28th July, 1905. Analyses of Indian coals.

HOLLAND, SIR T. H. . *Rec. Geol. Surv. Ind.*, XXVII, pp. 129-141, (1894). Mica-peridotites intrusive in the Lower Gondwanas of Bengal.

" " . Sketch of Mineral Resources of India. (1908).

HOLLAND, SIR. T. H. AND SAISE, DR. W. 'Igneous rocks of Giridih coal field, and their contact effects.' *Rec. Geol Surv. Ind.*, XXVIII, pp. 121-138, (1895).

GROVER, F. . . . 'Report on Seebpore coal.' *Journ. Soc. Arts*, LI, pp. 815-816, (1903).

SAISE, DR. W. . . *Rec. Geol. Surv. Ind.*, XXXI, p. 104, (1904). Assays of Raniganj coals.

Commercial Intelligence Department, India. *Financial & Commercial Statistics of British India*, (1904).

Commercial Intelligence Department, India. *Note on the Production & Consumption of coal in India up to the year 1907*, (Pub. 1908).

STONIER, G. A. . . Geological Map of the Raniganj coal field. (1905) 1 inch=1 mile.

VREDENBURG, E. W. . 'A summary of the geology of India.' Calcutta, (1907).

WHITE, JOHN . . 'Wastage in Bengal Coal-mining.' *Trans. Min. Geol. Inst. Ind.*, II, pp. 71-81, (1907).

PICKERING, W. H. AND SIMPSON, R. R. 'Fighting a colliery fire.' *Op. cit.*, II, pp. 127-151.

HOWARTH, W. . . 'Longwall method of working coal at Nursamuda.' *Op. cit.*, III, pp. 135-146, (1909).

CUNNINGHAME HUGHES, LT. COL. F. E. 'Proximate Analyses and Calorific values of Bengal coals.' *Op. cit.*, V, pp. 114-161, (1910).

FERMOR, DR. L. L. . 'Laterite', *Geol. Mag.*, New Series, Decade V, Vol. VIII, pp. 454-462; 507-516; 559-566, (1911).

,, ,, . *Trans. Min. Geol. Inst. Ind.*, XII, p. 50, (1918). Stresses the distinction between 'burnt coal' and 'jhama'.

,, ,, . 'Specific Gravity and Proximate Composition of Indian Vitrains.' *Rec. Geol. Surv. Ind.*, LXII, pp. 189-228, (1929).

,, ,, . 'Specific Gravity and Proximate composition of some Indian Durains.' *Op. cit.*, LXIII, pp. 358-377, (1930).

WALKER, H. AND SIMPSON, R. R. Geological map of the Raniganj coal-field. Published by the Mining and Geological Institute of India (1911). Scales 4 inches =1 mile, and 1 inch=1 mile.

WALKER, H. . . . 'The Raniganj coal-field.' *Trans. Min. Geol. Inst. Ind.*, VII, Pt. 3, (1913).

SIMPSON, R. R. . . 'The Coal-fields of India.' *Mem. Geol. Surv. Ind.*, XLI, (1913).

,, . 'Future of the Jharia coal-field.' *Trans. Min. Geol. Inst. Ind.*, XXIV, pp. 110-114, (1929).

,, . 'The Indian Mines Manual.' Pub. Calcutta, (1929).

HAYDEN, SIR H. H. . 'Coal Resources of the World.' International Congress, (1913).

AGABEG, E. C. . . 'Labour in Bengal coal-mines.' *Trans. Min. Geol. Inst. Ind.*, VIII, p. 26, (1913).

AGABEG, F. J. . . *Op. cit.*, IX, (1914) (Pres. Address) Conversion of the Sanctoria and Dishergarh seams into *jhama*, etc., etc.

COTTER, DR. G. DE P. 'A revised classification of the Gondwana System.' *Rec. Geol. Surv. Ind.*, XLVIII, p. 23, (1917).

BATHGATE, R. G. M. . *Trans. Min. Geol. Inst. Ind.*, XII, (1918). (Pres. Address) Losses during extraction, etc., etc.

WADIA, D. N. . . 'Geology of India' for students. (1919), Revised 1926.

Report of the Coal fields Committee, (1920); including report by Mr. Treharne Rees.

HENDRY, C. A. JOHN . *Trans. Min. Geol. Inst. Ind.*, XIV, p. 108, (1920) Sandstowing at Ramnagar colliery.

SIMMONS, W. . . . *Op. cit.*, XV, p. 122, (1921). Labour in Indian coal-mines.

Topographical map of Raniganj coal field. Scale 4 inches=1 mile. (1923-25) Published by the Survey of India, Calcutta.

RANDALL, W. . . . 'Froth Flotation of Indian coals.' *Rec. Geol. Surv. Ind.*, LVI, p. 229, (1924).

BRADSHAW, E. J. AND SAHNI, DR. B. 'Fossil Tree in Panchet series of Lower Gondwanas near Asansol.' *Op. cit.*, LVIII, pp. 75-79, (1925.)

Report of the Indian Coal Committee. (1925.)

FOX, DR. C. S. . . 'Raw Materials for the Iron and Steel Industry of India.' *Trans. Min. Geol. Inst. Ind.*, XX, pp. 87-194, (1925), and discussion, *ibid.* pp. 330-422, (1926).

" . . 'Low-Phosphorus Coking Coal in Giridih Coal-field.' *Rec. Geol. Surv. Ind.*, LIX, pp. 371-404, (1926).

FOX, DR. C. S. . . 'Barakar—Ironstone Shale boundary near Begunia; and Raniganj—Panchet boundary, near Asansol, Raniganj coal field.' *Op. cit.*, LX, pp.363-366, (1928).

" . . 'Note on Coking Tests with Gondwana coals.' *Op. cit.*, LXI, pp. 294-317, (1928).

" . . 'Indian Soft Coke.' *Capital*, 5th July, 1928 and 12th July, 1928.

" . . 'India's Reserves of Coking Coal and Iron Ores.' *Supra.*, 16th May, 1929.

" . . 'Quality of Indian Coals.' *Supra.*, 20th June, 1929.

" . . 'Discovery of Natural Coke.' *Supra.*, 27th June, 1929.

" . . 'Natural Coke in India.' *Supra.*, 29th August, 1929.

" . . 'The rise of the Jharia Coal field.' *Trans. Min. Geol. Inst. Ind.*, XXIV, pp. 97-109, (1929).

" . . 'The Jharia Coal-field.' *Mem. Geol. Surv. Ind.*, LVI, (1930).

COGGIN BROWN, DR. J. 'Indian Coal Problems.' *Bull. Indian Industries & Labour*, No. 36, Dec. 1926.

HOBSON, G. V. . . 'Sand supply in the upper Damodar river.' *Trans. Min. Geol. Inst. Ind.*, XXI, pp. 324-337, (1927) and discussion on same, *op. cit.*, XXII, pp. 23-27, (1927).

COWPER REED, DR. F. R. 'Permo-Carboniferous Marine fauna from Umaria coal-field, C. I.' *Rec. Geol. Surv. Ind.*, LX, pp. 367-398, (1927).

COWPER REED, DR. F. R., COTTER, DR. G. DE P. AND LAHIRI, H. M. 'The Permo-Carboniferous Succession in the Warcha Valley, Western Salt Range, Punjab.' *Op. cit.*, LXII, pp. 412-443, (1930).

GEE, E. R. . . 'Geology of Umaria Coal field.' *Op. cit.*, LX, pp. 399-410, (1927).

" . . 'Note on Panchet fossils from Alkusa, Raniganj coal field.' *Op. cit.*, LXIII, p. 207, (1930).

GEE, E. R. . . Correlation of Coal seams of the Raniganj field; *Trans. Min. Geol. Inst. Ind.* xxvi, Pt. 2.

'Ningah colliery.' *Op. cit.*, XXI, p. 371, (1927).

Publication of the Indian Coal Grading Board, containing list of graded coals, copies of the Act and Rules, and other information. (1928).

BANERJI, A. K. . . 'Note on the sedimentary petrography of some sandstones of the Raniganj stage from the Raniganj coal-field.' *Proc. Fifteenth Ind. Sci. Congr.* (*Asiat. Soc. Bengal*), pp. 291-292, (1928) (abstract).

RAU, S. SETHU RAMA . 'Tectonics of the Gondwana rocks of the Raniganj Coal-field.' *Op. cit.*, pp. 293-294, (abstract).

" " . 'Sedimentation in the Panchet epoch.' *Proc. Sixteenth Ind. Sci. Congr.* (*Asiat. Soc. Bengal*), p. 28, (1929) (abstract).

" " . 'Evidence of tectonic shearing in the Raniganj and Jharia coal-fields.' *Op. cit.*, p. 281, (1929) (abstract).

BARRACLOUGH, N. . 'Coal lost by fires and collapses in Indian coal mines.' *Rec. Geol. Surv. Ind.*, LXII, pp. 385-389, (1929).

MACKIE, J. . . . 'Hydraulic Stowing of Goaves.' *Capital*, 23rd May, 1929.

'Parbelia colliery.' *Trans. Min. Geol. Ins., Ind.*, XXIII, p. 188, (1929).

Geological map of Raniganj coalfield. Scale 4 inches=1 mile. (1930.)

GEOGRAPHICAL INDEX.

Locality.	Sheet No. (4″=1 mile.)	Latitude.			Longitude.			Page.
		°	′	″	°	′	″	
Banshgara . . .	23	23	37	30	87	17	45	74.
Banshra . . .	18	23	38	10	87	8	5	232.
Bansia	23	23	37	50	87	19	10	63, 74, 240.
Banskunri . . .	14	23	35	25	87	3	50	221.
Banspatali . . .	10	23	36	35	86	54	5	(See Plate 5).
Barabani (Baraboni) .	12	23	44	45	87	30	0	106, 112, 210, 212, 249, 315.
Bara Chak (Bora Chak) .	9	23	42	30	86	55	45	200, 310.
Bara Dhemo . . .	9	23	42	10	86	54	30	200, 204, 207, 286.
Baragaria . . .	23	23	37	0	87	22	0	74.
Baraigarha . . .	1	23	48	50	86	39	45	121.
Barajora . . .	17	23	45	10	87	14	50	241.
Barakar . . .	4	23	44	25	86	49	10	18, 45, 285, 311, 313.
Bara Pukhuriya . .	8	23	43	15	86	58	50	95, 206, 251.
Barhra	17	23	47	30	87	10	15	183.
Barmundih . . .	4	23	45	0	86	48	50	83, 84, 143, 145, 310.
Barol	12	23	44	20	87	6	50	225, 289.
Barwadih . . .	3	23	48	55	86	43	40	31.
Basudebpur . . .	8	23	47	30	86	53	0	32, 157.
Begunia . . .	4	23	43	50	86	48	50	45, 149, 151, 156, 191, 285, 306.
Bejdihi	9	23	41	20	86	52	40	205.
Belrui	8	23	43	0	86	53	50	310.
Berjor (Berjoi) . .	4	23	45	45	86	49	15	31.
Bhagrand . .	8	23	47	10	86	52	55	157.
Bhalkhuria . . .	1	23	48	30	86	41	15	123.
Bhamaria . . .	5	23	39	25	86	50	30	194, 199.

Locality.	Sheet No. (4″=1 mile.)	Latitude.			Longitude.			Page.
		°	′	″	°	′	″	
Charanpur . . .	12	23	44	15	87	2	20	13, 96, 106, 208, 210, 212, 247, 249, 211.
Chargarha (Chargora) .	1	23	50	50	86	41	45	38.
Chatabar . . .	4	23	44	30	86	43	50	14, 83, 84, 103, 118, 130, 134, 188, 190.
Chaukidanga (Chowkidanga).	18	23	40	30	87	8	30	224, 229, 251, 308.
Chaurashi (Chowrassi) .	5	23	39	55	86	46	40	194, 248.
Chelad	13	23	38	0	87	2	5	106.
Cheruinala . . .	4	23	45	40	86	43	30	134, 142.
Chhatrishganda . .	17	23	44	10	87	13	20	104, 241.
Chhora (Chora) . .	18	23	40	15	87	12	10	225, 230.
Chhota Dhemo . .	9	23	42	40	86	54	20	202, 205, 285.
Chhota Dhemua . .	5	23	42	0	86	50	40	202, 205.
Chhotkar . . .	7	23	48	50	86	57	20	95.
Chichurbil . . .	11	23	49	0	87	5	0	(See Plate 16).
Chichuria . . .	18	23	42	5	87	11	15	52, 112, 224, 226, 227, 240, 243, 248.
Chinakuri . . .	9	23	40	50	86	51	30	1, 3, 5, 206, 307.
Chinchuria . . .	8	23	44	30	86	58	5	114, 200, 201, 203, 248, 250, 285.
Chirkunda . . .	4	23	44	10	86	48	20	18, 79, 142, 146, 187.
Chulhapora . . .	1	23	48	35	86	40	10	121.
Churulia . . .	12	23	46	55	87	4	30	13, 41, 85, 106, 111, 114, 168, 174, 186, 289, 295.
D								
Dabar	7	23	48	0	86	55	5	32, 33, 161.
Dahibari . . .	4	23	43	45	86	45	15	118, 136, 141.

Locality.	Sheet No. (4″=1 mile.)	Latitude.			Longitude.			Page.
		°	′	″	°	′	″	
Dalabhdih . . .	4	23	47	0	86	44	0	130.
Dumarkanda . . .	4	23	43	30	86	47	45	142, 148, 190, 264, 304.
Durgapur . .	24	23	29	50	87	19	25	9, 51, 68, 296, 312.
E								
Egara	14	23	36	5	87	6	5	220, 254, 308.
Ethora (Aitura) . .	8	23	44	45	86	55	30	200, 307.
F								
Fatehpur . . .	9	23	42	15	86	55	15	207, 310.
G								
Gangpur . . .	16	23	48	25	87	12	30	184.
Gangpur . . .	3	23	48	45	86	44	10	29.
Gangutia . . .	5	23	42	40	86	50	30	201.
Ganrui	8	23	43	0	86	56	40	204, 286.
Garphalbari . . .	4	23	44	40	86	45	30	136, 140, 187, 312.
Ghagra	1	23	50	0	86	41	10	29, 30.
Ghoshik (Ghusick) . .	13	23	39	20	87	1	20	106, 211, 286, 311.
Gobindapur (Govindpur)	21	23	43	0	87	17	40	240, 243.
Gopalnagar . . .	14	23	36	0	87	1	40	222.
Gopalpur . . .	14	23	34	45	87	5	30	210.
Gopalpur . . .	8	23	43	45	86	56	25	56, 311.
Gopalpur . . .	5	23	39	40	86	47	20	194.
Gopalpur . . .	9	23	42	0	86	56	10	256.

Locality.	Sheet No. (4″=1 mile.)	Latitude.			Longitude.			Page.
		°	′	″	°	′	″	
Jamgram . . .	11	23	48	30	87	0	30	33, 112, 168, 172, 188, 198.
Jamsol	18	23	42	55	87	9	0	15, 289, 290.
Jamuria . . .	13	23	42	5	87	4	5	85, 106, 112, 208, 213.
Janra	1	23	49	50	86	41	40	30.
Jarkunri (Jorkuri) . .	11	23	49	10	87	5	40	178, 180.
Jaspur	3	23	48	10	86	45	40	31.
Jaynagar . . .	12	23	46	15	87	6	10	177.
Jayramdanga . .	12	23	44	35	87	0	15	606, 203, 210, 212, 249.
Jemeri	13	23	38	50	87	4	20	217, 219, 254.
Jemua	23	23	33	30	87	22	0	74.
Jemua	14	23	33	30	87	4	45	103, 210.
Jeruwadih . . .	1	23	49	20	86	40	40	28.
Jhanjra . . .	22	23	38	30	87	17	30	192, 239, 245.
Jhetarbad . . .	22	23	40	50	87	15	30	243.
Joba	13	23	40	25	87	3	35	252.
Josnadih . . .	4	23	45	40	86	43	50	130, 135, 140.
Jote Janaki . . .	18	23	40	10	87	8	45	225, 227, 229.
Junkundar . . .	4	23	43	40	86	46	30	143, 147.
Junut	9	23	40	0	86	52	0	54.
K								
Kaithi (Koiti) . .	13	23	42	50	87	3	40	48, 249.
Kajora	19	23	36	50	87	11	35	13, 224, 231, 233, 236, 254, 256.
Kalemathi (Kalimati) .	4	23	45	35	86	47	10	14, 118, 142, 145, 186.
Kalian Chak . . .	4	23	43	45	86	46	0	143, 147, 188.
Kalikapur . . .	14	23	35	20	87	3	30	13, 79, 221.

Locality.	Sheet No. (4″=1 mile.)	Latitude.			Longitude.			Page.
		°	′	″	°	′	″	
Kharimati Rampur .	11	23	50	0	87	4	20	179.
Khayrasole . . .	21	23	47	15	87	16	0	178, 183.
Khudka . . .	8	23	45	35	86	53	0	164.
Khusori. . . .	2	23	48	0	86	42	40	123, 131, 185.
Kija	8	23	48	0	86	58	20	33.
Kodokiari . . .	4	23	47	15	86	43	10	133.
Kolika	2	23	47	10	86	40	55	125.
Kolkund . . .	2	23	46	10	86	41	30	127.
Konardihi . . .	22	23	40	10	87	16	10	245.
Konda. . . .	22	23	42	55	87	18	20	242.
Kosumkanali . .	1	23	48	30	86	41	0	121, 122.
Kotaldihi . . .	13	23	38	40	87	0	15	210.
Kuardih . . .	4	23	46	45	86	44	20	137.
Kukhrakuri . . .	10	23	36	55	86	58	40	59.
Kultand . . .	4	23	45	50	86	47	30	32.
Kulti	4	23	44	0	86	50	45	17, 18, 47, 95, 292, 296, 313.
Kumardiha (Kuardih) .	13	23	38	40	87	1	40	211, 217, 257.
Kumarpur . . .	9	23	41	50	86	56	45	54, 207.
Kumhardubhi . .	4	23	44	30	86	47	0	17, 18, 105, 142, 146, 187. 309, 311, 314,
Kunustara . . .	18	23	39	5	87	7	50	226.
L								
Lachhipur . . .	9	23	42	30	86	53	25	205, 251, 286.
Lachhmanpur . .	8	23	45	10	86	52	15	96.
Lakhdih (Laikdih) . .	4	23	43	50	86	47	50	87, 118, 143, 147, 190, 311,
Lakrajoria . . .	8	23	46	35	86	51	20	32.

Locality.	Sheet No. (4″=1 mile.)	Latitude.			Longitude.			Page.
		°	′	″	°	′	″	
Mothani . . .	9	23	41	45	86	54	0	200 204.
Mohanpur . . .	8	23	47	0	86	57	0	167, 227.
Mohishila (Muslia) . .	13	23	39	40	86	59	50	55, 106, 216, 219, 222.
Moldanga . . .	22	23	39	40	87	15	25	246, 255.
Mugma	4	23	46	20	86	43	30	89, 127, 130, 133, 187, 313.
Mukundarpur . .	18	23	38	35	87	12	35	225.
Mulliahara (Malliarah) .	..	23	28	0	87	16	0	101.
Murulia . . .	6	23	36	40	86	50	30	102, 194, 199, 255, 286.
N								
Nadiha	8	23	43	30	86	56	55	206, 253.
Nadiha (Nodiha) . .	5	23	39	50	86	46	55	13, 194, 197, 248, 250, 309.
Nandai	8	23	47	50	86	57	25	32, 33, 149, 165.
Nandi	13	23	42	50	87	5	40	211, 248.
Napara	12	23	44	55	86	59	30	203.
Napur	19	23	35	5	87	8	25	221, 238.
Narasamuda . .	9	23	41	30	86	55	50	96, 200, 204, 208, 257, 311, 315.
Narayanpur (Narrainpur)	5	23	40	25	86	47	20	194, 309.
Niamatpur . . .	8	23	43	0	86	52	50	202.
Nimcha . . .	13	23	38	20	87	5	30	218, 254, 311.
Nimsa	17	23	43	0	87	12	50	15
Ninga (Ningah) . .	13	23	40	30	87	2	20	210, 212, 250, 311.
Nirsa	4	23	46	30	86	43	10	133, 187.
Nirsa	2	23	47	10	86	42	30	125, 187.
Nituria	5	23	39	45	86	49	50	192, 194, 197.
Nuni	8	23	44	30	86	57	45	202.
Nutandanga . . .	22	23	42	30	87	19	50	242.

Locality.	Sheet No. (4″=1 mile.)	Latitude.			Longitude.			Page.
		°	′	″	°	′	″	
Parulia	23	23	36	10	87	20	10	63, 75.
Patasbana . . .	4	23	44	20	86	44	55	141.
Patlabari . . .	5	23	43	0	86	45	40	14, 83, 84, 104, 118, 143, 147, 188.
Patmohana (Patmohna) .	9	23	40	55	86	53	45	200, 207, 257.
Petana	4	23	44	35	86	50	45	105, 151, 156, 161.
Phulberya . . .	8	23	46	25	86	54	30	162, 164.
Pithakiari . . .	2	23	47	0	86	42	10	126.
Podadih . . .	4	23	47	10	86	46	30	37.
Poradih . . .	4	23	45	20	86	48	35	143.
Puapur	5	23	38	50	86	46	0	194, 197, 250.
Purana Chatti . .	8	23	45	40	86	58	20	95.
Purushottampur . .	22	23	41	30	87	16	50	13, 104, 192, 239, 241, 243.
R								
Radhaballavpur . .	8	23	47	25	86	55	40	162, 295.
Ragdih	4	23	45	20	86	43	40	142.
Raghunathbati . .	8	23	43	25	86	55	30	200, 204, 251, 310.
Raghunath Chak . .	19	23	35	15	87	7	15	18, 215, 309.
Raghunathpur . .	5	23	41	30	86	46	50	35, 184.
Rajpura . . .	4	23	46	20	86	46	15	32, 142.
Ramdhara . .	7	23	49	35	86	58	10	34, 169, 295.
Ramjibanpur . .	8	23	43	5	86	55	10	310.
Ramkanali . . .	2	23	47	45	86	40	30	123, 124, 133.
Ramnagar . . .	4	23	45	15	86	50	0	13, 37, 79, 84, 94, 149, 153, 187, 189, 299, 304, 316.
Ramnagar . . .	21	23	43	50	87	15	50	112, 242, 245.

Locality.	Sheet No. (4″=1 mile.)	Latitude.			Longitude.			Page.
		°	′	″	°	′	″	
Satgram . . .	13	23	39	30	87	5	30	214, 251.
Satpukhuriya . .	13	23	42	10	87	0	40	96, 209, 222, 256, 287, 311.
Sattar	12	23	45	0	87	5	10	289.
Sekpur	13	23	41	50	87	6	30	74, 106, 114, 192, 208, 210, 212, 224, 248.
Semalya (Samla) . .	17	23	44	45	87	12	10	52, 192, 239, 243, 286.
Shampur . . .	2	23	45	50	86	42	30	14, 83, 84, 103, 118, 126, 188, 190.
Shankarpur (Sunkerpur) .	18	23	40	0	87	14	20	224, 231, 236, 243, 255.
Shanrmara . . .	5	23	41	40	86	46	30	35.
Shibpur (Sibpur) . .	12	23	43	30	87	3	40	14, 48, 211, 213, 243, 249, 311.
Shitala	9	23	42	30	86	58	20	208.
Shitalpur (Seetalpur) .	5	23	41	15	86	50	30	200, 201, 204, 316.
Shripur . . .	13	23	41	20	87	2	30	85, 208, 212, 215, 252.
Shyamdi . . .	8	23	46	55	86	55	25	149, 161, 165, 167, 295.
Shyamsundarpur . .	22	23	39	10	87	16	0	245.
Siarsol	14	23	37	45	87	6	35	85, 106, 113, 210, 217, 219, 226, 231, 253, 269, 309.
Siduli	18	23	39	0	87	12	50	225, 231, 236, 255.
Sitarampur . . .	6	23	43	15	86	54	30	19, 47, 96, 202, 286, 307, 309, 315.
Siulibari . . .	4	23	45	0	86	47	10	145, 187.
Sonachora . . .	19	23	38	0	87	9	20	225, 232.
Sonpur	18	23	41	45	87	13	50	192, 224, 229, 243.
Srikrishnapur . .	22	23	40	10	87	21	40	74.
Sudi	8	23	43	50	86	55	10	85, 203.
Sultanpur . . .	11	23	49	30	87	5	0	178, 180.

MGIPC—M—VIII-4-17—22-1-32—950

INDEX.

The principal page references are indicated in heavier type. For names of collieries, see Geographical Index.

D

MGIPC—M—VIII-4-17—22-1-31—950.

PLATE I.

Old coal-exporting ghât, near Egara, Raniganj coalfield. This view illustrates the remains of one of the old exporting depôts on the northern bank of the Damodar river, from which the coal was exported to Calcutta during the monsoon period, at a time previous to the construction of the East Indian railway to Raniganj in 1815.

E. R. Gee, Photo.

G. S. I. Calcutta

OLD COAL-EXPORTING GHAT, NEAR EGARA, RANIGANJ COALFIELD.

PLATE 2.

Basal Talchir boulder-bed, Adjai river, Raniganj coalfield. The boulder-bed of the basal Talchirs, resting on the Archæans of the southern bank of the Adjai river, north of Panuria, comprises sub-angular and rounded boulders of crystalline rocks and quartzite, included in a greenish, argillaceous, sandy matrix.

E. R. Gee, Photo.

G. S. I. Calcutta.

BASAL TALCHIR BOULDER-BED, ADJAI RIVER, RANIGANJ COALFIELD.

PLATE 3.

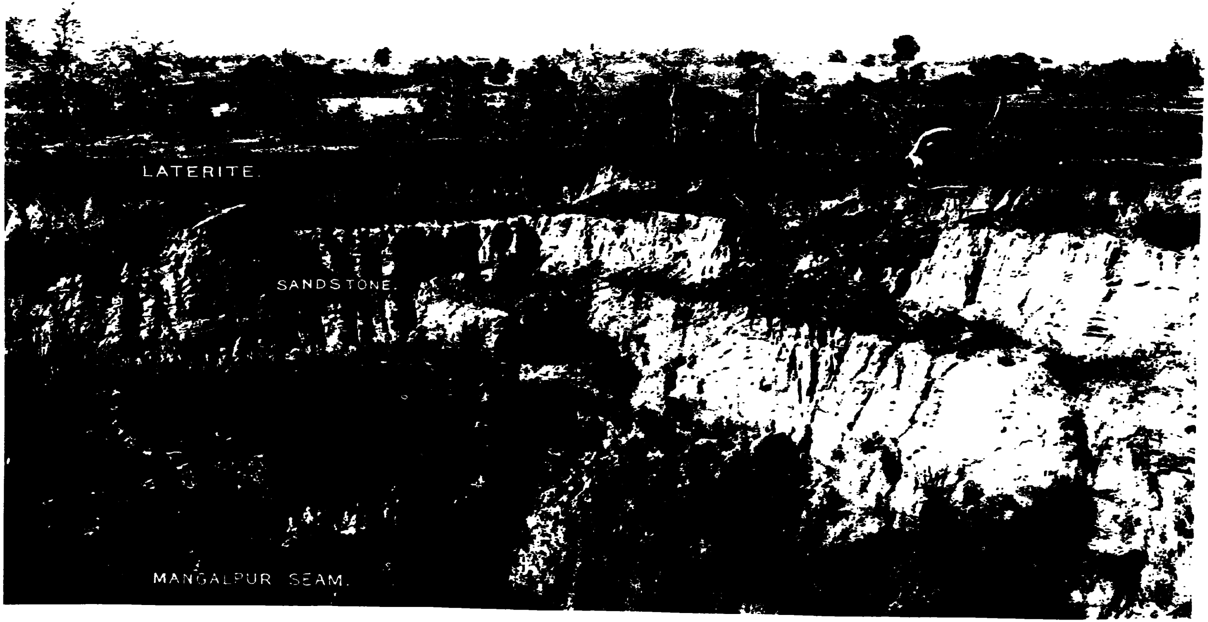
False-bedded Barakar sandstones, Chanch, Raniganj coalfield. This photograph illustrates the marked false-bedding of many of the Barakar sandstones, in particular those of the uppermost Barakar measures, which overlie the Chanch-Begunia coal seam.

C. S. Fox, Photo. *G. S. I. Calcutta.*

FALSE-BEDDED BARAKAR SANDSTONES, CHANCH, RANIGANJ COALFIELD.

PLATE 4.

Section of the Raniganj measures, Mangalpur, Raniganj coalfield. The quarry section includes a capping of laterite consisting of about two feet of hard consolidated rock, followed below by about three to four feet of rubbly laterite. Several feet of soft, decomposed Raniganj sandstone immediately underlie the rubbly laterite and pass down into fine-textured grey and greenish-grey massive sandstones, which form the roof of the thick Mangalpur coal seam.



E. R. Gee, Photo.

SECTION OF THE RANIGANJ MEASURES, MANGALPUR, RANIGANJ COALFIELD

G. S. I. Calcutta

PLATE 5.

Panchet clays and sandstones, near Banspatali, Raniganj coalfield. The gently-inclined Panchet clays (predominantly dark-red in colour with thin light-tinted bands) alternate with yellow-grey soft sandstones and constitute the upper part of the Panchet series of the southern part of the coalfield.

S. Sethu Rama Rau, Photo.

G. S. I. Calcutta.

PANCHET CLAYS AND SANDSTONES, NEAR BANSPATALI, RANIGANJ COALFIELD.

PLATE 6.

Fig. 1. Quartzose laterite and lateritic gravels, near Parulia, Raniganj coalfield. The section includes a capping of consolidated hard laterite, passing below into lateritic gravels; the latter rest unconformably on the soft yellow-grey sandstones (? = Durgapur beds) of the extreme eastern part of the field.

Fig. 2. Ferruginous sandstone among laterite, near Srikrishnapur, Raniganj coalfield. The laterite of the eastern end of the coalfield includes masses of ferruginous grit and sandstone, which is also undergoing superficial lateritisation.

E. R. Gee, Photo. *G. S. I. Calcutta.*

FIG. 1. QUARTZOSE LATERITE AND LATERITIC GRAVELS, NEAR PARULIA, RANIGANJ, COALFIELD.

A. K. Banerji, Photo. *G. S. I. Calcutta*

FIG. 2. FERRUGINOUS SANDSTONE AMONG LATERITE, NEAR SRIKRISHNAPUR, RANIGANJ COALFIELD.

PLATE 7.

Mica-peridotite dyke intersecting Pusai seam, Raniganj coalfield. On either side of this four-foot mica-peridotite dyke (P), which here intersects the Pusai coal seam in the Sonbad *nala*, the coked *jhama* coal (J) exhibits a pronounced columnar structure.

E. R Gee, Photo. *G. S. I. Calcutta.*

MICA-PERIDOTITE DYKE INTERSECTING PUSAI SEAM, RANIGANJ COALFIELD.

PLATE 8.

Mica-peridotite sill, Kudia *nala*, Raniganj coalfield. The more irregular type of mica-peridotite sill intrusions intersecting a coal seam of the Shampur measures is illustrated in this photograph. At intervals the sill (P) swells out into masses, lenticular in cross-section. The conversion of the coal into *jhama* (J) is very pronounced.

S. Sethu Rama Rau, Photo. *G. S. I. Calcutta.*

MICA-PERIDOTITE SILL INTERSECTING COAL SEAM, KUDIA NALA, RANIGANJ COALFIELD.

PLATE 9.

Mica-peridotite sill intersecting Bahira '5' seam, Raniganj coalfield. Exposed in the eastern side of the quarry, west of Bahira village.

E. R. Gee, Photo.

G. S. I. Calcutta.

MICA-PERIDOTITE SILL INTERSECTING BAHIRA SEAM, RANIGANJ COALFIELD.

PLATE 10.

Fig. 1. Mica-peridotite sill, Kudia *nala*, Raniganj coalfield. The sill of mica-peridotite (weathered into 'white trap') exhibits a marked uniformity in thickness. The sill is intruded along the top of a seam of shale and coal of the middle Barakar measures. Massive sandstones overlie the intrusion.

Fig. 2. The Salma dolerite dyke, Raniganj coalfield. This dolerite dyke, about 120 feet wide, follows a very direct trend across the Raniganj field. Its outcrop is marked by the rectangular blocks of superficially weathered dolerite, as illustrated on the northern bank of the Damodar river.

Memoirs, Vol. LXI, Pl. 10.

FIG. 1. MICA-PERIDOTITE SILL, KUDIA NALA, RANIGANJ COALFIELD.

E. R. Gee, Photo. G. S. I. Calcutta.

FIG. 2. THE SALMA DOLERITE DYKE, RANIGANJ COALFIELD.

PLATE 11.

Quarrying the Damagaria seam, Damagaria colliery (Messrs. Turnbull Bros., Ltd.), Raniganj coalfield. This seam, 100 feet in total thickness, includes a lower section of good quality coal, which is being extracted. At the outcrop the seam passes into grey earthy fireclays, as shown in the photograph.

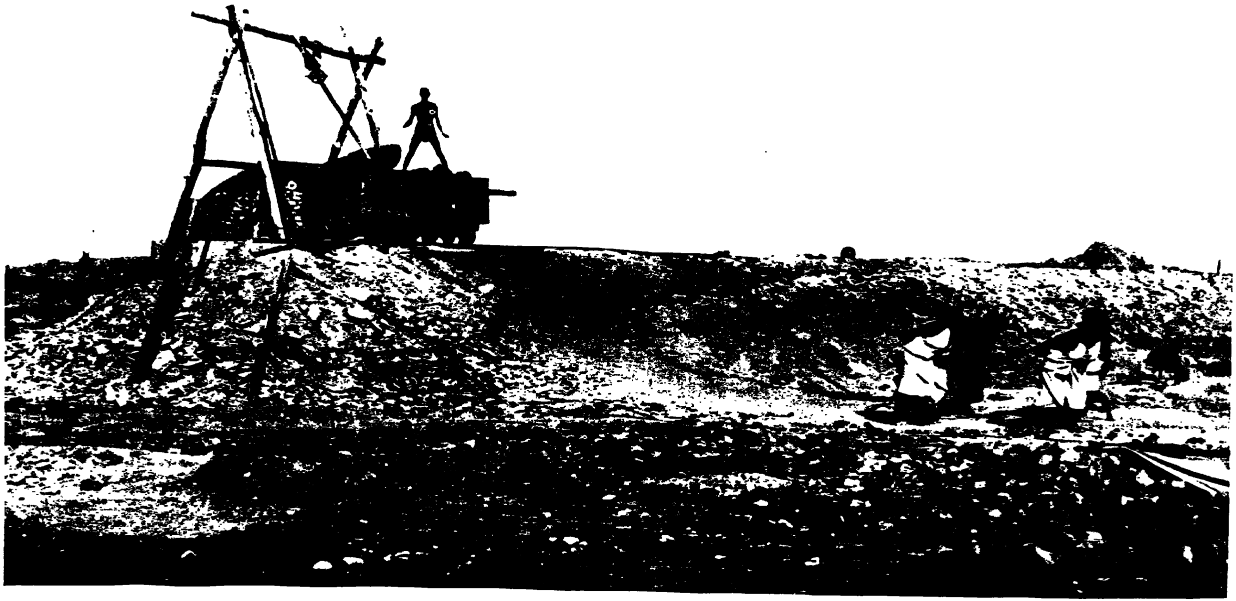
E. R. Gee, Photo. G. S. I. Calcutta

QUARRYING THE DAMAGARIA SEAM, DAMAGARIA COLLIERY, RANIGANJ COALFIELD.

PLATE 12.

Primitive method of raising coal near Barabani, Raniganj coalfield. At this small colliery, female-labour was still employed (in 1927) for the purpose of raising coal from a shallow shaft. The 'buckets' of coal were hauled to the surface by a rope passed over a pulley-wheel at the top of the shaft and were then emptied into the adjoining tubs and transported to the depôt.

Memoirs, Vol. LXI, Pl. 12.



E. R. Gee, Photo. *G. S. I. Calcutta.*

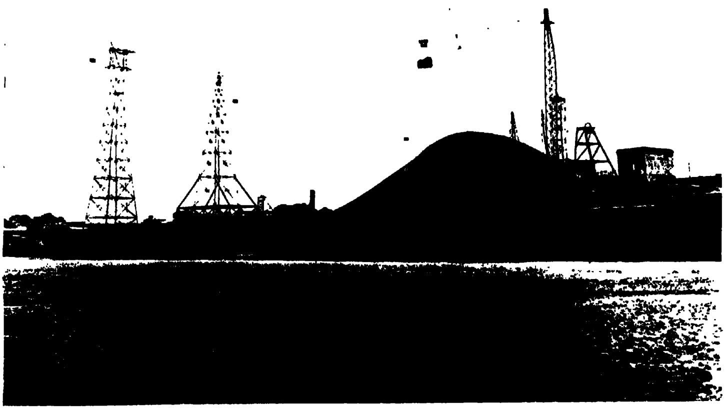
PRIMITIVE METHOD OF RAISING COAL NEAR BARABANI, RANIGANJ COALFIELD.

PLATE 13.

Fig. 1. Ningah colliery (Messrs. Turner Morrison & Co., Ltd.), Raniganj coalfield. The photograph illustrates the headgears of the two main 1,300-foot shafts of Ningah colliery, completed, down to the Poniati seam, in 1928.

Fig. 2. Aerial ropeways (Messrs. Bird & Co., Ltd.), Saltor, Raniganj coalfield. This photograph illustrates the aerial ropeway of Saltor colliery, on the south bank of the Damodar river. The more distant ropeway is employed in the conveyance of coal from the pits of Saltor island, to the depôt on the mainland; the one in the foreground includes the mechanical 'grab' and 'drag-line' by which sand is obtained from the bed of the Damodar and transported to the river-bank for the purpose of sand-stowing.

FIG. 1. NINGAH COLLIERY, (TURNER MORRISON & Co. Ltd.,) RANIGANJ COALFIELD.



E. R. Gee, Photos. *G. S. I. Calcutta.*

FIG. 2. AERIAL ROPEWAYS, (BIRD & Co. Ltd.,) SALTOR, RANIGANJ COALFIELD.

PLATE 14.

Fig. 1. Blast furnaces, Bengal Iron Co., Ltd. (Messrs. Martin & Co., Ltd.), Kulti, Raniganj coalfield.

Fig. 2. Pottery works (Messrs. Burn & Co., Ltd.), Raniganj, Raniganj coalfield.

C. S. Fox, Photo.

FIG. 1. BLAST FURNACES, (BENGAL IRON Co. Ltd.,) KULTI, RANIGANJ.

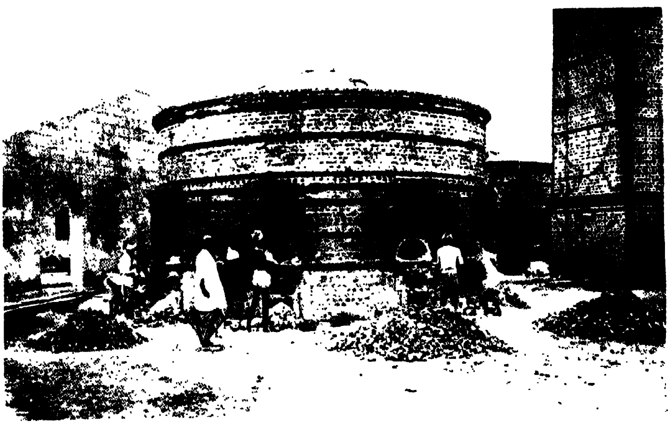
Photo. by permission of Messrs. Burn & Co. Ltd. *G. S. I. Calcutta.*

FIG. 2. POTTERY WORKS, (BURN & Co. Ltd.,) RANIGANJ

PLATE 15.

Figs. 1 & 2. Fireclay and Silica works (Messrs. Bird & Co., Ltd)., Kumhardubhi Raniganj coalfield.

FIG. 1.



By permission of Messrs. Bird & Co. Ltd.,

G. S. I. Calcutta.

FIG. 2.

FIGS. 1 & 2. FIRECLAY AND SILICA WORKS, BIRD & CO. LTD., KUMHARDUBHI, RANIGANJ COALFIELD.

VOL. X, 1877.

Part 1 (*out of print*).—Annual report for 1876. Geological notes on Great Indian Desert between Sind and Rajputana. Cretaceous genus Omphalia near Nameho lake. Tibet, about 75 miles north of Lhassa. Estheria in Gondwana formation. Vertebrata from Indian tertiary and secondary rocks. New Emydine from the upper tertiaries of Northern Punjab. Observations on under-ground temperature.

Part 2 (*out of print*).—Rocks of the Lower Godavari. 'Atgarh Sandstones' near Cuttack. Fossil floras in India. New or rare mammals from the Siwaliks. Aravali series in North-Eastern Rajputana. Borings for coal in India. Geology of India.

Part 3 (*out of print*).—Tertiary zone and underlying rocks in North-West Punjab. Fossil floras in India. Erratics in Potwar. Coal explorations in Darjiling district. Limestones in neighbourhood of Barakar. Forms of blowing machine used by smiths of Upper Assam. Analyses of Raniganj coals.

Part 4 (*out of print*).—Geology of Mahanadi basin and its vicinity. Diamonds, gold, and lead ores of Sambalpur district. 'Eryon Comp. Barrovensis' McCoy, from Sripermatur group near Madras. Fossil floras in India. The Blaini group and 'Central Gneiss' in Simla, Himalayas. Tertiaries of North-West Punjab. Genera Chœromeryx and Rhagatherium.

VOL. XI, 1878.

Part 1.—Annual report for 1877. Geology of Upper Godavari basin, between river Wardha and Godavari, near Sironcha. Geology of Kashmir, Kishtwar, and Pangi. Siwalik mammals. Palæontological relations of Gondwana system. 'Erratics in Punjab.'

Part 2 (*out of print*).—Geology of Sind (second notice). Origin of Kumaun lakes. Trip over Milam Pass, Kumaun. Mud volcanoes of Ramri and Cheduba. Mineral resources of Ramri, Cheduba and adjacent islands.

Part 3 (*out of print*).—Gold industry in Wynaad. Upper Gondwana series in Trichinopoly and Nellore-Kistna districts. Senarmontite from Sarawak.

Part 4.—Geographical distribution of fossil organisms in India. Submerged forest on Bombay Island.

VOL. XII, 1879.

Part 1.—Annual report for 1878. Geology of Kashmir (third notice). Siwalik mammalia. Siwalik beds. Tour through Hangrang and Spiti. Mud eruption in Ramri Island (Arakan), Braunite, with Rhodonite, from Nagpur, Central Provinces. Palæontological notes from Satpura coal-basin. Coal importations into India.

Part 2 (*out of print*).—Mohpani coal-field. Pyrolusite with Psilomelane at Gosalpur, Jabalpur district. Geological reconnaissance from Indus at Kushalgarh to Kurram at Thal on Afghan frontier. Geology of Upper Punjab.

Part 3 (*out of print*).—Geological features of northern Madura, Padukota State, and southern parts of Tanjore and Trichinopoly districts included within limits of sheet 80 of Indian Atlas. Cretaceous fossils from Trichinopoly district, collected in 1877-78. Sphenophyllum and other Equisetaceæ with reference to Indian form Trizygia Speciosa, Royle (Sphenophyllum Trizygia, Ung.). Mysorin and Atacamite from Nellore district. Corundum from Khasi Hills. Joga neighbourhood and old mines on Norbadda.

Part 4.—"Attock Slates" and their probable geological position. Marginal bone of undescribed tortoise, from Upper Siwaliks, near Nila, in Potwar, Punjab. Geology of North Arcot district. Road section from Murree to Abbottabad.

VOL. XIII, 1880.

Part 1.—Annual report for 1879. Geology of Upper Godavari basin in neighbourhood of Sironcha. Geology of Ladak and neighbouring districts. Teeth of fossil fishes from Ramri Island and Punjab. Fossil genera Nöggerathia, Stbg., Noggerathiopsis, Fstm., and Rhiptozamites, Schmalh., in palæozoic and secondary rocks of Europe, Asia and Australia. Fossil plants from Kattywar, Shekh Badin, and Sirgujah. Volcanic foci of eruption in Konkan.

Part 2.—Geological notes. Palæontological notes on lower trias of Himalayas. Artesian wells at Pondicherry, and possibility of finding sources of water-supply at Madras.

Part 3.—Kumaun lakes. Celt of palæolithic type in Punjab. Palæontological notes from Karharbari and South Rewa coal-fields. Correlation of Gondwana flora with other floras. Artesian wells at Pondicherry. Salt in Rajputana. Gas and mud eruptions on Arakan coast on 12th March 1879 and in June 1843.

Part 4 (*out of print*).—Pleistocene deposits of Northern Punjab, and evidence they afford of extreme climate during portion of that period. Useful minerals of Arvali region. Correlation of Gondwana flora with that of Australian coal-bearing system. Reh or alkali soils and saline well waters. Reh soils of Upper India. Naini Tal landslip, 18th September 1880.

Vol. XIV, 1881.

Part 1.—Annual report for 1880. Geology of part of Dardistan, Baltistan, and neighbouring districts. Siwalik carnivora. Siwalik group of Sub-Himalayan region. South Rewah Gondwana basin. Ferruginous beds associated with basaltic rocks of north-eastern Ulster, in relation to Indian laterite. Rajmahal plants. Travelled blocks of the Punjab. Appendix to 'Palæontological notes on lower trias of Himalayas', Mammalian fossils from Perim Island.

Part 2 (out of print).—Nahan-Siwalik unconformity in North-Western Himalaya. Gondwana vertebrates. Ossiferous beds of Hundes in Tibet. Mining records and mining record office of Great Britain; and Coal and Metalliferous Mines Act of 1872 (England). Cobaltite and danaite from Khetri mines, Rajputana; with remarks on Jaipurite (Syepoorite). Zinc-ore (Smith-sonite and Blende) with barytes in Karnul district, Madras. Mud eruption in island of Cheduba.

Part 3 (out of print).—Artesian borings in India. Oligoclase granite at Wangtu on Sutlej, North-West Himalayas. Fish-plate from Siwaliks. Palæontological notes from Hazaribagh and Lohardagga districts. Fossil carnivora from Siwalik hills.

Part 4 (out of print).—Artesian borings in India. Oligoclase granite at Wangtu on Sutlej, region, central and eastern. Native antimony obtained at Pulo Obin, near Singapore. Turgite from Juggiapett, Kistnah District, and zinc carbonate from Karnul, Madras. Section from Dalhousie to Pangi, *via* Sach Pass, South Rewah Gondwana basin. Submerged forest on Bombay Island.

Vol. XV, 1882.

Part 1 (out of print).—Annual report for 1881. Geology of North-West Kashmir and Khagan. Gondwana labyrinthodonts (Siwalik and Jamna mammals). Geology of Dalhousie, North-West Himalaya. Palm leaves from (tertiary) Murree and Kasauli beds in India. Iridosmine from Noa-Dihing river, Upper Assam, and Platinum from Chutia Nagpur. On (1) copper mine near Yongri hill, Darjiling district: (2) arsenical pyrites in same neighbourhood: (3) kaolin at Darjiling. Analyses of coal and fire-clay from Makum coal-field, Upper Assam. Experiments on coal of Pind Dadun Khan, Salt-range, with reference to production of gas, made April 29th, 1881. International Congress of Bologna.

Part 2 (out of print).—Geology of Travancore State. Warkilli beds and reported associated deposits at Quilon, in Travancore. Siwalik and Narbada fossils. Coal-bearing rocks of Upper Ror and Mand rivers in Western Chutia Nagpur. Pench river coal-field in Chhindwara district, Central Provinces. Boring for coal at Engsein, British Burma. Sappers in North-Western Himalaya. Eruption of mud volcanoes in Cheduba.

Part 3 (out of print).—Coal of Mach (Much) in Bolan Pass, and of Sharigh on Harnai route between Sibi and Quetta. Crystals of stilbite from Western Ghats, Bombay. Traps of Darang and Mandi in North-Western Himalayas. Connexion between Hazara and Kashmir series. Umaria coal-field (South Rewah Gondwana basin). Daranggiri coal-field, Garo Hills, Assam. Coal in Myanoung division, Henzada district.

Part 4 (out of print).—Coal-fields of Mysore. Borings for coal at Beddadanol, Godávari district, in 1874. Supposed occurrence of coal on Kistna.

Vol. XVI, 1883.

Part 1.—Annual report for 1882. Richthofenia, Kays. (Anomia Lawrenciana, Koninck). Geology of South Travancore. Geology of Chamba. Basalts of Bombay.

Part 2 (out of print).—Synopsis of fossil vertebrata of India. Bijori Labyrinthodont skull of Hippotherium antilopinum. Iron ores, and subsidiary materials for manufacture of iron, in north-eastern part of Jabalpur district. Laterite and other manganese-ore occurring at Gosulpore, Jabalpur district. Umaria coal-field.

Part 3 (out of print).—Microscopic structure of some Dalhousie rocks. Lavas of Aden. Probable occurrence of Siwalik strata in China and Japan. Mastodon angustiden in India. Traverse between Almora and Mussoorree. Cretaceous coal measures at Borsora, in Khasia Hills, near Laour, in Sylhet.

Part 4 (out of print).—Palæontological notes from Daltonganj and Hutar coal-fields in Chota Nagpur. Altered basalts of Dalhousie region in North-Western Himalayas. Microscopic structure of some Sub-Himalayan rocks of tertiary age. Geology of Jaunsar and Lower Himalayas. Traverse through Eastern Khasia, Jaintia, and North Cachar Hills. Native lead from Maulmain and chromite from the Andaman Islands. Fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Irrigation from wells in North-Western Provinces and Oudh.

Vol. XVII, 1884.

***Part 1*.**—**Annual report for 1883. Smooth-water anchorages for mud-banks of Narrakal and Alleppy on Travancore coast. Billa Surgam and other caves in Karnool district. Geology of Chauari and Sihunta parganas of Chamba. Lyttonin, Waagen, in Kuling series of Kashmir.**

Part 2 (out of print).—Earthquake of 31st December 1881. Microscopic structure of some Himalayan granites and gneissose granites. Choi coal exploration. Re-discovery of fossils in Siwalik beds. Mineral resources of Andaman Islands in neighbourhood of Port Blair. Intertrappean beds in Deccan and Laramie group in Western North America.

Part 3 (out of print).—Microscopic structure of some Arvali rocks. Section along Indus from Peshawar Valley to Salt-range. Sites for boring in Raigarh-Hingir coal-field (first notice). Lignite near Raipore, Central Provinces. Turquoise mines of Nishapur, Khorassan. Fiery eruption from Minbyin mud vulcano of Cheduba Island, Arakan. Langrin coal-field, South-Western Khasia Hills. Umaria coal-field.

Part 4 (out of print).—Geology of part of Gangasulan pargana of British Garhwal. Slates and schists imbedded in gneissose granite of North-West Himalayas. Geology of Takht-i-Suleiman. Smooth-water anchorages of Travancore coast. Auroferous sands of the Subansiri river, Pondicherry lignite, and phosphatic rocks at Musuri. Billa Surgam caves.

Vol. XVIII, 1885.

Part 1 (out of print).—Annual report for 1884. Country between Singareni coal-field and Kistna river. Geological sketch of country between Singareni coal-field and Hyderabad. Coal and limestone in Doigrung river near Golaghat, Assam. Homotaxis, as illustrated from Indian formations. Afghan field notes.

Part 2—Fossiliferous series in Lower Himalaya, Garhwal. Age of Mandhali series in Lower Himalaya. Siwalik camel (Camelus Antiquus, nobis ex Falc. and Caut. MS.). Geology of Chamba. Probability of obtaining water by means of artesian wells in plains of Upper India. Artesian sources in plains of Upper India. Geology of Aka Hills. Alleged tendency of Arakan mud volcanoes to burst into eruption most frequently during rains. Analyses of phosphatic nodules and rock from Mussooree.

Part 3 (out of print).—Geology of Andaman Islands. Third species of Merycopotamus. Percolation as affected by current. Pirthala and Chandpur meteorites. Oil-wells and coal in Thayetmyo District, British Burma. Antimony deposits in Maulmain district. Kashmir earthquake of 30th May 1885. Bengal earthquake of 14th July 1885.

Part 4 (out of print).—Geological work in Chhattisgarh division of Central Provinces. Bengal earthquake of 14th July 1885. Kashmir earthquake of 30th May 1885. Excavations in Billa Surgam caves. Nepaulite. Sabetmahet meteorite.

Vol. XIX, 1886.

Part 1 (out of print).—Annual report for 1885. International Geological Congress of Berlin. Palæozoic Fossils in Olive group of Salt-range. Correlation of Indian and Australian Coal-bearing beds. Afghan and Persian Field-notes. Section from Simla to Wangtu, and petrological character of Ambhibolites and Quartz-Diorites of Sutlej valley.

Part 2 (out of print).—Geology of parts of Bellary and Anantapur districts. Geology of Upper Dehing basin in Singpho Hills. Microscopic characters of eruptive rocks from Central Himalayas. Mammalia of Karnul Caves. Prospects of finding coal in Western Rajputana. Olive group of Salt-range. Boulder-beds of Salt-range. Gondwana Homotaxis.

Part 3 (out of print).—Geological sketch of Vizagapatam district, Madras. Geology of Northern Jesalmer. Microscopic structure of Malani rocks of Arvali region. Malanjkhandi copper-ore in Balaghat district, C. P.

Part 4 (out of print).—Petroleum in India. Petroleum exploration at Khátan. Boring in Chhattisgarh coal-fields. Field-notes from Afghanistan: No. 3, Turkistan. Fiery eruption from one of the mud volcanoes of Cheduba Island, Arakan. Nammianthal aerolite. Analysis of gold dust from Meza valley, Upper Burma.

Vol. XX, 1887.

Part 1 (out of print).—Annual report for 1886. Field-notes from Afghanistan: No. 4, from Turkistan to India. Physical geology of West British Garhwal; with notes on a route traversed through Jaunsar-Bawar and Tiri-Garhwal. Geology of Garo Hills. Indian image-stones. Soundings recently taken off Barren Island and Narcondam. Talchir boulder-beds. Analysis of Phosphatic Nodules from Salt-range, Punjab.

Part 2.—Fossil vertebrata of India. Echinoidea of cretaceous series of Lower Narbada Valley. Field-notes: No. 5—to accompany geological sketch map of Afghanistan and North-Eastern Khorassan. Microscopic structure of Rajmahal and Deccan traps. Dolerite of Chor. Identity of Olive series in east, with speckled sandstone in west of Salt-range in Punjab.

Part 3.—Retirement of Mr. Medlicott. J. B. Mushketoff's Geology of Russian Turkistan. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaun, Section I. Geology of Simla and Jutogh. 'Lalitpur' meteorite.

Part 4 (out of print).—Points in Himalayan geology. Crystalline and Metamorphic rocks of Lower Himalaya, Garhwal, and Kumaon, Section II. Iron industry of western portion of Raipur. Notes on Upper Burma. Boring exploration in Chhattisgarh coal-field (Second notice). Pressure Metamorphism, with reference to foliation of Himalayan Gneissose Granite. Papers on Himalayan Geology and Microscopic Petrology.

Vol. XXI, 1888.

Part 1.—Annual report for 1887. Crystalline and metamorphic rocks of Lower Himalaya, Garhwal, and Kumaun, Section III. Birds-nest of Elephant Island, Mergui Archipelago. Exploration of Jesalmer, with a view to discovery of coal. Facetted pebble from boulder-bed ('speckled sandstone') of Mount Chel in Salt-range, Punjab. Nodular stores obtained of Colombo.

Part 2 (out of print).—Award of Wollaston Gold Medal, Geology Society of London, 1888. Dharwar System in South India. Igneous rocks of Raipur and Balaghat, Central Provinces. Sangar Marg and Mohowgale coal-fields, Kashmir.

Part 3 (out of print).—Manganese Iron and Manganese Ores of Jabalpur. 'The Carboniferous Glacial Period.' Pre-tertiary sedimentary formation of Simla region of Lower Himalayas.

Part 4 (out of print).—Indian fossil vertebrates. Geology of North-West Himalayas. Blown sand rock sculpture. Nummulites in Zanskar. Mica traps from Barakar and Raniganj.

Vol. XXII, 1889.

Part 1 (out of print).—Annual report for 1888. Dharwar System in South India. Wajra Karur diamonds, and M. Chapter's alleged discovery of diamonds in pegmatite. Generic position of so-called Plesiosaurus indicus. Flexible sandstone or Itacolumite, its nature, mode of occurrence in India, and cause of its flexibility. Siwalik and Narbada Chelonia.

Part 2 (out of print).—Indian Steatite. Distorted pebbles in Siwalik conglomerate, "Carboniferous Glacial Period." Notes on Dr. W. Waagen's "Carboniferous Glacial Period". Oil-fields of Twingoung and Beme, Burma. Gypsum of Nehal Nadi, Kumaun. Materials for pottery in neighbourhood of Jabalpur and Umaria.

Part 3 (out of print).—Coal outcrops in Sharigh Valley, Baluchistan. Trilobites in Neobolus beds of Salt-range. Geological notes. Cherra Poonjee coal-field, in Khasia Hills. Cobaltiferous Matt from Nepál. President of Geological Society of London on International Geological Congress of 1888. Tin-mining in Mergui district.

Part 4 (out of print).—Land-tortoises of Siwaliks. Pelvis of a ruminant from Siwaliks. Assays from Sambhar Salt-Lake in Rajputana. Manganiferous iron and Manganese Ores of Jabalpur. Palagonite-bearing traps of Rájmahál hills and Deccan. Tin-smelting in Malay Peninsula. Provisional Index of Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones and Quarry Stones in Indian Empire: Part 1.

Vol. XXIII, 1890.

Part 1 (out of print).—Annual report for 1889. Lakadong coal-field, Jaintia Hills. Pectoral and pelvic girdles and skull of Indian Dicynodonts. Vertebrate remains from Nagpur district (with description of fish-skull). Crystalline and metamorphic rocks of Lower Himalayas, Garhwál and Kumaun, Section IV. Bivalves of Olive group Salt-range. Mud-banks of Travancore coast.

Part 2 (out of print).—Petroleum explorations in Harnai district, Baluchistan. Sapphire Mines of Kashmir. Supposed Matrix of Diamond at Wajra Karur, Madras. Sonapet Gold-field. Field-notes from Shan Hills (Upper Burma). New species of Syringosphæridæ.

Part 3 (out of print).—Geology and Economic Resources of Country adjoining Sind-Pishin Railway between Sharigh and Spintangi, and of country between it and Khattan. Journey through India in 1888-89, by Dr. Johannes Walther. Coal-fields of Lairungao, Maosandram, and Mao-be-lar-kar, in the Khasi Hills. Indian Steatite. Provisional Index of Local Distribution of Important Minerals, Miscellaneous Minerals, Gem Stones, and Quarry Stones in Indian Empire.

Part 4 (out of print).—Geological sketch of Naini Tal; with remarks on natural conditions, governing mountain slopes. Fossil Indian Bird Bones. Darjiling Coal between Lisu and Ramthi rivers. Basic Eruptive Rocks of Kadapah Area. Deep Boring at Lucknow. Coal Seam of Dore Ravine, Hazara.

Vol. XXIV, 1891.

Part 1 (*out of print*).—Annual report for 1890. Geology of Salt-range of Punjab, with re-considered theory of Origin and Age of Salt-Marl. Graphite in decomposed Gneiss (Laterite) in Ceylon. Glaciers of Kabru, Pandim, etc. Salts of Sambhar Lake in Rajputana, and 'Reh' from Aligarh in North-Western Provinces. Analysis of Dolomite from Salt-range, Punjab.

Part 2 (*out of print*).—Oil near Moghal Kot, in Sherani country, Suleiman Hills. Mineral Oils from Suleiman Hills. Geology of Lushai Hills. Coal-fields in Northern Shan States. Reported Namséka Ruby-Mine in Mainglôn State. Tourmaline (Schorl) Mines in Mainglôn State. Salt-spring near Bawgyo, Thibaw State.

Part 3 (*out of print*).—Boring in Daltonganj Coal-field, Palamow. Death of Dr. P. Martin, Duncan. Pyroxenic varieties of Gneiss and Scapolite-bearing Rocks.

Part 4 (*out of print*).—Mammalian Bones from Mongolia. Darjeeling Coal Exploration. Geology and Mineral Resources of Sikkim. Rocks from the Salt-range, Punjab.

Vol. XXV, 1892.

Part 1 (*out of print*).—Annual report for 1891. Geology of Thal Chotiáli and part of Mari country. Petrological Notes on Boulder-bed of Salt-range, Punjab. Sub-recent and Recent Deposits of valley plains of Quetta, Pishin, and Dashti-i-Bedalot; with appendices on Chamans of Quetta; and Artesian water-supply of Quetta and Pishin.

Part 2 (*out of print*).—Geology of Safed Kôh. Jherria Coal-field.

Part 3 (*out of print*).—Locally of Indian Tscheffkinite. Geological Sketch of country, north of Bhamo. Economic resources of Amber and Jade mines area in Upper Burma. Iron-ores and Iron industries of Salem District. Riebeckite in India. Coal on Great Tenasserim River, Lower Burma.

Part 4 (*out of print*).—Oil Springs at Mogal Kot in Shirani Hills. Mineral Oil from Suleiman Hills. New Amber-like Resin in Burma. Triassic Deposits of Salt-range.

Vol. XXVI, 1893.

Part 1 (*out of print*).—Annual report for 1892. Central Himalayas. Jadeite in Upper Burma. Burmite, new Fossil Resin from Upper Burma. Prospecting Operations, Mergui District, 1891-92.

Part 2 (*out of print*).—Earthquake in Baluchistan of 20th December 1892. Burmite, new Amber-like fossils from Upper Burma. Alluvial deposits and Subterranean water-supply of Rangoon.

Part 3 (*out of print*).—Geology of Sherani Hills. Carboniferous Fossils from Tenasserim. Boring at Chandernagore. Granite in Tavoy and Mergui.

Part 4 (*out of print*).—Geology of country between Chappar Rift and Harnai in Baluchistan. Geology of part of Tenasserim Valley with special reference to Tendau-Kamapying Coal-field. Magnetite containing Manganese and Olumina. Hislopite.

Vol. XXVII, 1894.

Part 1 (*out of print*).—Annual report for 1893. Bhaganwala Coal-field, Salt-range, Punjab.

Part 2 (*out of print*).—Petroleum from Burma. Singareni Coal-field, Hyderabad (Deccan), Gohna Landslip, Garhwal.

Part 3 (*out of print*).—Cambrian Formation of Eastern Salt-range. Girdih (Karharbari) Coal-fields. Chipped (?) Flints in Upper Miocene of Burma. Velates Schmideliana, Chemn., and Provelates grandis, Sow, sp., in Tertiary Formation of India and Burma.

Part 4 (*out of print*).—Geology of Wuntho in Upper Burma. Echinoids from Upper Cretaceous System of Baluchistan. Highly Phosphatic Mica Peridotites intrusive in Lower Gondwana Rocks of Bengal. Mica-Hypersthene-Hornblende-Peridotite in Bengal.

Vol. XXVIII, 1895.

Part 1.—Annual report for 1894. Cretaceous Formation of Pondicherry. Early allusion to Barren Island. Bibliography of Barren island and Narcondam from 1884 to 1894.

Part 2 (*out of print*).—Cretaceous Rocks of Southern India and geographical conditions during later cretaceous times. Experimental Boring for Petroleum at Sukkur from October 1893 to March 1895. Tertiary system in Burma.

Part 3 (*out of print*).—Jadeite and other rocks, from Tammaw in Upper Burma. Geology of Tochi Valley. Lower Gondwanas in Argentina.

Part 4 (*out of print*).—Igneous Rocks of Giridih (Kurhurbaree) Coal-field and their Contact Effects. Vindhyan system south of Sone and their relation to so-called Lower Vindhyans. Lower Vindhyan area of Sone Valley. Tertiary system in Burma.

Vol. XXIX, 1896.

Part 1 (out of print).—Annual report for 1895. Acicular inclusions in Indian Garnets. Origin and Growth of Garnets and of their Micropegmatitic intergrowths in Pyroxenic rocks.

Part 2 (out of print).—Ultra-basic rocks and derived minerals of Chalk (Magnesite) hills, and other localities near Salem, Madras. Corundum localities in Salem and Coimbatore districts, Madras. Corundum and Kyanite in Manbhum district, Bengal. Ancient Geography of "Gondwana-land." Notes.

Part 3.—Igneous Rocks from the Tochi Valley. Notes.

Part 4 (out of print).—Steatite mines, Minbu district, Burma. Lower Vindhyan (Sub-Kaimur) area of Sone Valley, Rewah. Notes.

Vol. XXX, 1897.

Part 1.—Annual report for 1896. Norite and associated Basic Dykes and Lava-flows in Southern India Genus Vertebraria. On Glossopteris and Vertebraria.

Part 2.—Cretaceous Deposits of Pondicherri. Notes.

Part 3 (out of print).—Flow structure in igneous dyke. Olivine-norite dykes at Coonoor. Excavations for corundum near Palakod, Salem District. Occurrence of coal at Palana in Bikaner. Geological specimens collected by Afghan-Baluch Boundary Commission of 1896.

Part 4.—Nemalite from Afghanistan. Quartz-barytes rock in Salem district, Madras Presidency. Worn femur of Hippopotamus irravadicus, Cant. and Falc., from Lower Pliocene of Burma. Supposed coal at Jaintia, Baxa Duars. Percussion Figures on micas. Notes.

Vol. XXXI, 1904.

Part 1 (out of print).—Prefatory Notice. Copper-ore near Komai, Darjeeling district. Zewan beds in Vihi district, Kashmir. Coal deposits of Isa Khel, Mianwali district, Punjab. Um-Rileng coal-beds, Assam. Sapphirine-bearing rock from Vizagapatam District. Miscellaneous Notes. Assays.

Part 2 (out of print).—Lt.-Genl. C. A. McMahon. Cyclolobus Haydeni Diener. Auriferous Occurrences of Chota Nagpur, Bengal. On the feasibility of introducing modern methods of Coke-making at East Indian Railway Collieries, with supplementary note by Director, Geological Survey of India. Miscellaneous Notes.

Part 3 (out of print).—Upper Palæozoic formations of Eurasia. Glaciation and History of Sind Valley. Halorites in Trias of Baluchistan. Geology and Mineral Resources of Mayurbhanj. Miscellaneous Notes.

Part 4 (out of print).—Geology of Upper Assam. Auriferous Occurrences of Assam. Curious occurrence of Scapolite from Madras Presidency. Miscellaneous Notes. Index.

Vol. XXXII, 1905.

Part 1 (out of print).—Review of Mineral production of India during 1898—1903.

Part 2 (out of print).—General report, April 1903 to December 1904. Geology of Provinces of Tsang and U in Tibet. Bauxite in India. Miscellaneous Notes.

Part 3 (out of print).—Anthracolithic Fauna from Subansiri Gorge, Assam. Elephas Antiquus (Namadicus) in Godavari Alluvium. Triassic Fauna of Tropites Limestone of Byans. Amblygonite in Kashmir. Miscellaneous Notes.

Part 4.—Obituary notices of H. B. Medlicott and W. T. Blanford. Kangra Earthquake of 4th April 1905. Index to Volume XXXII.

Vol. XXXIII, 1906.

Part 1 (out of print).—Mineral Production of India during 1904. Pleistocene Movement in Indian Peninsula. Recent Changes in Course of Nam-tu River, Northern Shan States. Natural Bridge in Gokteik Gorge. Geology and Mineral Resources of Narnaul District (Patiala State). Miscellaneous Notes.

Part 2 (out of print).—General report for 1905 Lashio Coal-field, Northern Shan States. Namma, Mansang and Man-se-le Coal-fields, Northern Shan States, Burma. Miscellaneous Notes.

Part 3 (out of print).—Petrology and Manganese-ore Deposits of Sausar Tahsil, Chhindwara district, Central Provinces. Geology of part of valley of Kanhan River in Nagpur and Chhindwara districts, Central Provinces Manganite from Sandur Hills. Miscellaneous Notes.

Part 4 (out of print).—Composition and Quality of Indian Coals. Classification of the Vindhyan System. Geology of State of Panna with reference to the Diamond-bearing Deposits. Index to Volume XXXIII.

Vol. XXXIV, 1906.

Part 1 (out of print).—Fossils from Halorites Limestone of Bambanag Cliff, Kumaon. Upper Triassic Fauna from Pishin District, Baluchistan. Geology of portion of Bhutan Coal Occurrences in Foot-hills of Bhutan. Dandli Coal-field: Coal outcrops in Kotli Tehsil of Jammu State. Miscellaneous Notes.

Part 2 (out of print).—Mineral production of India during 1905. Nummulites Douvillei, with remarks on Zonal Distribution of Indian Nummulites. Auriferous Tracts in Southern India. Abandonment of Collieries at Warora, Central Provinces. Miscellaneous Notes.

Part 3 (out of print).—Explosion Craters in Lower Chindwin District, Burma. Lavas of Pavagad Hill. Gibbsite with Manganese-ore from Talevadi, Belgaum district, and Gibbsite from Bhekowli, Satara District. Classification of Tertiary System in Sind with reference to Zonal distribution of Eocene Echinoidea.

Part 4 (out of print).—Jaipur and Nazira Coal-fields, Upper Assam. Makum Coal-fields between Tirap and Namdang Streams. Kobat Anticline, near Seiktein, Myingyan district, Upper Burma. Asymmetry of Penangyat-Singu Anticline, Upper Burma, Northern part of Gwegyo Anticline, Myingyan District, Upper Burma. Breynia Multituberculata, from Nari of Baluchistan and Sind. Index to Volume XXXIV.

Vol. XXXV, 1907.

Part 1 (out of print).—General report for 1906. Orthophragmina and Lepidocyclina in Nummulitic Series. Meteoric Shower of 22nd October 1903 at Dokachi and neighbourhood, Dacca district.

Part 2 (out of print).—Indian Aerolites. Brine-wells at Bawgyo, Northern Shan States. Gold-bearing Deposits of Loi Twang, Shan States. Physa Prinsepii in Maestrichtian strata of Baluchistan. Miscellaneous Notes.

Part 3.—Preliminary survey of certain Glaciers in North West Himalaya. A.—Notes on certain Glaciers in North-West Kashmir.

Part 4.—Preliminary survey of certain Glaciers in North-West Himalaya. B.—Notes on certain Glaciers in Lahaul. C.—Notes on certain Glaciers in Kumaon. Index to Volume XXXV.

Vol. XXXVI, 1907-08.

Part 1 (out of print).—Petrological Study of Rocks from hill tracts, Vizagapatam district, Madras, Madras Presidency. Nepheline Syenites from hill tracts, Vizagapatam district, Madras Presidency. Stratigraphical Position of Gangamopteris Beds of Kashmir. Volcanic outburst of Late Tertiary Age in South Hsenwi, N. Shan States. New Suidæ from Bugti Hills, Baluchistan. Permo-Carboniferous Plants from Kashmir.

Part 2 (out of print).—Mineral Production of India during 1906. Ammonites of Bagh Beds. Miscellaneous Notes.

Part 3 (out of print).—Marine fossils in Yenangyaung oil-field, Upper Burma. Freshwater shells of genus Batissa in Yenangyaung oil-field, Upper Burma. New Species of Dendrophyllia from Upper Miocene of Burma. Structure and age of Taungtha hills, Myingyan district, Upper Burma. Fossils from Sedimentary rocks of Oman (Arabia). Rubies in Kachin hills, Upper Burma. Cretaceous Orbitoides of India. Two Calcutta Earthquakes of 1906. Miscellaneous Notes.

Part 4 (out of print).—Pseudo-Fucoids from Pab sandstones at Fort Munro, and from Vindhyan series. Jadeite in Kachin Hills, Upper Burma. Wetchok-Yedwet Pegu outcrop, Magwe district, Upper Burma. Group of Manganates, comprising Hollandite, Psilomelane and Coronadite. Occurrence of Wolfram in Nagpur district, Central Provinces. Miscellaneous Notes. Index to Volume XXXVI.

Vol. XXXVII, 1908-09.

Part 1 (out of print).—General report for 1907. Mineral Production of India during 1907. Occurrence of striated boulders in Blaini formation of Simla. Miscellaneous Notes.

Part 2 (out of print).—Tertiary and Post-Tertiary Freshwater Deposits of Baluchistan and Sind. Geology and Mineral Resources of Rajpipla State. Suitability of sands in Rajmaha. Hills for glass manufacture. Three new Manganese-bearing minerals:—Vredenburgite, Sitaparite and Juddite. Laterites from Central Provinces. Miscellaneous Notes.

Part 3 (out of print).—Southern part of Gwegyo Hills, including Payagyigon-Ngashandaung Oil field. Silver-lead mines of Bawdwin, Northern Shan States. Mud volcanoes of Arakan Coast, Burma.

Part 4.—Gypsum Deposits in Hamirpur district, United Provinces. Gondwanas and related marine sedimentary system of Kashmir. Miscellaneous Notes. Index to Volume XXXVII.

Vol. XXXVIII, 1909-10.

Part 1. General report for 1908. Mineral Productions of India during 1908.

Part 2 (out of print).—Osterea latimarginata in "Yenangyaung stage" of Burma. China-clay and Fire-clay deposits in Rajmahal Hills. Coal at Gilhurria in Rajmahal hills. Pegu Inlier at Ondwe, Magwe district, Upper Burma. Salt Deposits of Rajputana. Miscellaneous Notes.

Part 3.—Geology of Sarawan, Jhalawan, Mekran and the State of Las Bela. Hippurite-bearing Limestone in Seistan and Geology of adjoining region. Fusulinidæ from Afghanistan. Miscellaneous Notes.

Part 4.—Geology and Prospects of Oil in Western Prome and Kama, Lower Burma (including Namayan, Padaung, Taungbogyi and Ziaing). Recorrelation of Pegu system in Burma with notes on Horizon of Oil-bearing Strata (including Geology of Padaukpin, Banbyin and Aukmanein). Fossil Fish Teeth from Pegu system, Burma. Northern part of Yenangyat Oil-field. Iron Ores of Chanda, Central Provinces. Geology of Aden Hinterland. Petrological Notes on rocks near Aden. Upper Jurassic Fossils near Aden. Miscellaneous Notes. Index to Volume XXXVIIII.

Vol. XXXIX, 1910.

Quinquennial Review of Mineral Production of India during 1904 to 1908.

Vol. XL, 1910.

Part 1.—Pre-Carboniferous Life-Provinces. Lakes of Salt Range in the Punjab. Preliminary survey of certain Glaciers in Himalaya. D.—Notes on certain glaciers in Sikkim. New Mammalian Genera and Species from Tertiaries of India.

Part 2 (out of print).—General Report for 1909. Mineral Production of India during 1909.

Part 3.—Revised Classification of Tertiary Freshwater Deposits of India. Revision of Silurian-Trias Sequence in Kashmir. Fenestella-bearing beds in Kashmir.

Part 4 (out of print).— Alum Shlade and Alum Manufacture, Kalabagh, Mianwali district, Punjab. Coal-fields in North-Eastern Assam. Sedimentary Deposition of Oil. Miscellaneous Notes. Index to Volume XL.

Vol. XLI, 1911-12.

Part 1.—Age and continuation in Depth of Manganese-ores of Nagpur-Balaghat Area, Central Provinces. Manganese-ore deposits of Rangpur State, Bengal, and Distribution of Gondite Series in India. Baluchistan Earthquake of 21st October 1909. Identity of Ostrea, Promensis, Noetling, from Pegu System of Burma and Ostrea Digitalina, Eichwald, from Miocene of Europe. Mr. T. R. Blyth. Miscellaneous Notes.

Part 2.—General report for 1910. Devonian Fossils from Chitral, Persia, Afghanistan and Himalayas. Sections in Pir Panjal Range and Sind Valley, Kashmir.

Part 3.—Mineral Production of India during 1910. Samarskite and other minerals in Nellore District, Madras Presidency. Coal in Namchik Valley, Upper Assam. Miscellaneous Notes.

Part 4.—Pegu-Eocene Succession in Minbu District near Ngape. Geology of Henzada District, Burma. Geology of Lonar Lake, with note on Lonar Soda Deposit. International Geological Congress of Stockholm. Miscellaneous Notes. Index to Volume XLI.

Vol. XLII, 1912.

Part 1.—Survival of Miocene Oyster in Recent Seas. Silurian Fossils from Kashmir. Blödite from Salt Range. Gold-bearing Deposits of Mong Long, Hsipaw State, Northern Shan States, Burma. Steatite Deposits, Idar State. Miscellaneous Notes.

Part 2.—General Report for 1911. Dicotyledeonous Leaves from Coal Measures of Assam. Poting Glacier, Kumaon, Himalaya, June 1911. Miscellaneous Notes.

Part 3.—Mineral Production of India during 1911. Kodurite Series.

Part 4.—Geological Reconnaissance through Dehong Valley, being Geological Results of Abor Expedition, 1911-12. Traverse Across the Naga Hills of Assam. Indian Aërolites. Miscellaneous Notes.

Vol. XLIII, 1913.

Part 1 (out of print).—General Report for 1912. Garnet as a Geological Barometer. Wolframite in Tavoy District, Lower Burma. Miscellaneous Notes.

Part 2 (out of print).—Mineral Production of India during 1912. Relationship of the Himalaya to the Indo-Gangetic Plain and the Indian Peninsula. Hambergite from Kashmir.

Part 3.—Contributions to the geology of the Province of Yünnan in Western China: I.—Bhamo-Têng-Yüeh Area. II.—Petrology of Volcanic Rocks of Têng-Yüeh District. The Kriana Hills. Banswal Aërolite.

Part 4.—Gold-bearing Alluvium of Chindwin River and Tributaries. Correlation of Siwaliks with Mammal Horizons of Europe. Contributions to the Geology of the Province of Yünnan in Western China: III.—Stratigraphy of Ordovician and Silurian Beds of Western Yünnan, with Provisional Palæontological Determinations. Notes on "Camarocrinus Asiaticus" from Burma.

Vol. XLIV, 1914.

Part 1 (out of print).—General Report for 1913. Carbonaceous Aërolite from Rajputana Nummulites as Zone Fossils, with description of some Burmese species.

Part 2.—Contributions to the Geology of the Province of Yünnan in Western China: IV.—Country around Yünnan Fu. Dyke of white Trap from Pench Valley Coal-field, Chhindwara District, Central Provinces. Mineral concessions during 1913.

Part 3.—Coal-seams near Yaw River, Pakokku District, Upper Burma. The Monazite Sands of Travancore. Lower Cretaceous Fauna from Gieumal Sandstone and Chikkim series. Indarctos salmontanus Pilgrim. Future Beheading of Son and Rer Rivers by Hasdo.

Part 4.—Salt Deposits of Cis Indus Salt Range. Teeth referable to Lower Siwalik Creodont genus Dissopsalis Pilgrim. Glaciers of Dhauli and Lissar Valleys, Kumaon, Himalaya, September 1912. Miscellaneous Notes.

Vol. XLV, 1915.

Part 1.—New Siwalik Primates. Brachiopoda of Namyau Beds of Burma. Miscellaneous Note.

Part 2.—General Report for 1914. Note on Sivaelurus and Paramachaerodus.

Part 3.—Mineral Production of India during 1914. Three New Indian Meteorites. Kuttippuram, Shupiyan and Kamsagar. Dentition of Tragulid Genus Dorcabune, Hematite Crystal of Corundiform Habit from Kajlidongri, Central India.

Part 4.—Geology of country near Ngahlaingdwin. Geology of Chitral, Gilgit and Pamirs.

Vol. XLVI, 1915.

Quinquennial Review of Mineral Production of India for 1909 to 1913.

Vol. XLVII, 1916.

Part 1.—General Report for 1915. Eocene Mammals from Burma. Miscellaneous Notes.

Part 2.—The Deccan Trap Flows of Linga, Chhindwara District, Central Provinces. Iron Ore Deposits of Twinngé, Northern Shan States.

Part 3.—Obituary: B. C. Burton. The Mineral Production of India during 1915. Flemingostrea, an eastern group of Upper Cretaceous and Eocene Ostreidæ, with descriptions of two new species.

Part 4.—Contributions to the Geology of the Province of Yünnan in Western China: 5.—Geology of parts of the Salween and Mekong Valleys. A fossil wood from Burma. The Visuni and Ekh Khera Aërolites.

Vol. XLVIII, 1917.

Part 1.—General Report for 1916. A revised classification of the Gondwana System.

Part 2.—Mineral Production of India during 1916. Mammal collections from Basal Beds of Siwaliks.

Part 3.—Crystallography and Nomenclature of Hollandite. Geology and Ore Deposits of Bawdwin Mines. Miscellaneous Notes.

Part 4.—Biana-Lalsot Hills in Eastern Rajputana. Origin of the Laterite of Seoni, Central Provinces.

Vol. XLIX, 1918-19.

Part 1.—General Report for 1917. Cassiterite Deposits of Tavoy. Les Echinides des "Bagh Beds."

Part 2.—Mineral Production of India during 1917. Support of Mountains of Central Asia.

Part 3.—Structure and Stratigraphy in North-West Punjab. Aquamarine Mines of Daso, Baltistan. Srimangal Earthquake of July 8th, 1918.

Part 4.—Possible Occurrence of Petroleum in Jammu Province: Preliminary Note on the Nar-Budhan Dome, of Kotli Tehsil in the Punch Valley. Submerged Forests at Bombay Intra-Trappens and Silicified Lava from Hyderabad, S. India.

Vol. L, 1919.

Part 1.—General Report for 1918. Potash Salts of Punjab Salt Range and Kohat. Origin and history of Rock-salt Deposits of Punjab and Kohat.

Part 2.—Tungsten and Tin in Burma. Inclination of Thrust-plane between Siwalik and Murree zone near Kotli, Jammu. Two New Fossil Localities in Garo Hills. Sanni Sulphur Mine. Miscellaneous Notes.

Part 3 (out of print).—Mineral Production of India during 1918. Gastropoda Fauna of Old Lake-beds in Upper Burma. Galena Deposits of North-Eastern Putao.

Part 4.—Pitchblende, Monazite and other minerals from Pichhli, Gaya district, Bihar and Orissa. Natural Gas in Bituminous Salt from Kohat. Mineral Resources of Central Provinces. Miscellaneous Notes.

VOL. LI, 1920-21.

Part 1.—General Report for 1919. Pseudo-crystals of Graphite from Travancore. Mineral related to Xenotime from Manbhum District, Bihar and Orissa Province. Coal Seams of Foot-Hills of the Arakan Yoma, between Letpan Yaw in Pakokku and Ngapé in Minbu, Upper Burma. Observations on "Physa Prinsepii," Sowerby and on a Clionid Sponge that burrowed in its shell.

Part 2.—Classification of fossil Cypræidæ. Sulphur near the confluence of the Greater Zab with the Tigris, Mesopotamia. Miscellaneous Notes.

Part 3.—Mineral Production of India during 1919. Results of a Revision of Dr. Noetling's Second Monograph on the Tertiary Fauna of Burma. Marine Fossils collected by Mr. Pinfold in the Garo Hills.

Part 4.—Illustrated comparative Diagnoses of Fossil Terebridæ from Burma. Indian Fossil Viviparæ. On a New fossil Unionid from the Intertrappean beds of Peninsular India. Unionidæ from the Miocene of Burma.

VOL. LII, 1921.

Quinquennial Review of Mineral Production of India for 1914—1918.

VOL. LIII, 1921.

Part 1.—General Report for 1920. Antimony deposit of Thabyu, Amherst district. Antimony deposits of Southern Shan States. Geology and Mineral Resources of Eastern Persia. Miscellaneous Notes.

Part 2.—Comparative Diagnoses of Pleurotomidæ from Tertiary Formation of Burma. Comparative Diagnoses of Conidæ and Cancellariidæ from Tertiary of Burma. Stratigraphy Fossils and Geological Relationships of Lameta Beds of Jubbulpore. Rocks near Lameta Ghat (Jubbulpore District).

Part 3 (out of print).—Obituary: Frederick Richmond Mallet. Mineral Production of India during 1920. Mineral Resources of Bihar and Orissa.

Part 4.—Stratigraphy of the Singu-Yenangyat Area. Analysis of Singu Fauna. Sulphur Deposits of Southern Persia. A Zone-Fossil from Burma: Ampullina (Megatylotus) Birmanica.

VOL. LIV, 1922.

Part 1.—General Report for 1921. Contributions to the Geology of the Province of Yünnan in Western China: VI.—Traverses between Tali Fu and Yünnan Fu. Geology of Takki Zam Valley, and Kaniguram-Makin Area, Waziristan. Geology of Thayetmyo and neighbourhood, including Padaukbin. Bitumen in Bombay Island.

Part 2.—Mineral Production of India during 1921. Iron Ores of Singhbhum and Orissa. Geological Results of the Mount Everest Reconnaissance Expedition. Northern Extension of the Wolfram-bearing Zone in Burma. Miscellaneous Note.

Part 3.—Obituary: Rupert William Palmer. Indian Tertiary Gastropoda, IV.—Olividæ, Harpidæ, Marginellidæ, Volutidæ and Mitridæ, with comparative diagnoses of new species. Structure of Cuticle in Glossopteris angustifolia Brongn. Revision of some Fossil Balanomorph Barnacles from India and the East Indian Archipelago. Contributions to the Geology of the Province of Yünnan in Western China: 7.—Reconnaissance Surveys between Shunning Fu, Chingtung Ting and Tali Fu. 8.—Traverse down Yang-tze-chaing Valley from Chin-chaing-kai to Tui-li-Chou. Boulder Beds beneath Utatur Stage, Trichinopoly District. Miscellaneous Notes.

Part 4.—Geology of Western Jaipur. Geological Traverses from Assam to Myitkyina through Hukong Valley: Myitkyina to Northern Putao: and Myitkyina to Chinese Frontier. Oligocene Echinoidea collected by Rao Bahadur S. Sethu Rama Rau in Burma. Mineral Resources of Kalhapur State. Kunghka and Manmaklang Iron Ore Deposits, Northern Shan States, Burma.

VOL. LV, 1923-24.

Part 1.—General Report for 1922. Indian Tertiary Gastropoda, No. 5, Fusidæ, Turbinellidæ, Chrysodomidæ, Strepturidæ, Buccinidæ, Nassidæ, Columbellidæ, with short diagnoses of new species. Geological Interpretation of some Recent Geodetic Investigations (being a second Appendix to the Memoir on the structure of the Himalayas and of the Gangetic Plain as elucidated by Geodetic Observations in India).

Part 2.—Obituary: Ernest (Watson) Vredenburg. Fossil Molluscs from Oil-Measures of Dawna Hills, Tenasserim. Armoured Dinosaur from Lameta Beds of Jubbulpore. Fossils forms of Placuna. Phylogeny of some Turbinellidæ. Recent Falls of Aerolites in India. Geology of part of Khasi and Jaintia Hills, Assam.

Part 3.—Mineral Production of India during 1922. Lignitic Coal-fields in Karewa formation of Kashmir Valley. Basic and Ultra-Basic Members of the Charnockite Series in the Central Provinces. China Clay of Karalgi, Khanapur, Belgaum District.

Part 4.—Obituary: Henry Hubert Hayden. Oil Shales of Eastern Amherst, Burma, with a Sketch of Geology of Neighbourhood. Provisional list of Palæozoic and Mesozoic Fossils collected by Dr. Coggin Brown in Yünnan. Fall of three Meteoric Irons in Rajputana on 20th May 1921. Miscellaneous Note.

VOL. LVI, 1924-25.

Part 1.—General Report for 1923. Mineral Deposits of Burma.

Part 2.—Mineral Production of India during 1923. Soda rocks of Rajputana.

Part 3.—Gyrolite and Okenite from Bombay. Freshwater Fish from oil-measures of Dawna Hills. Fossil Ampullariid from Poonch, Kashmir. Calcareous Alga belonging to Triploporelleæ (Dasycladaceæ) from Tertiary of India. Froth Flotation of Indian Coals. Submarine Mud Eruptions off Arakan Coast, Burma. Cretaceous Fossils from Afghanistan and Khorasan.

Part 4.—Merua Meteorite. Stegodon Ganesa in Outer Siwaliks of Jammu. Land and Freshwater Fossil Molluscs from Karewas of Kashmir. Burmese Lignites from Namma, Lashio and Pauk. Maurypur Salt Works.

VOL. LVII, 1925.

Quinquennial Review of Mineral Production of India for 1919-1923. Price 5 Rs. 10 As.

VOL. LVIII, 1925-26.

Part 1.—General Report for 1924. Fossil Tree in Panchet Series of Lower Gondwanas near Asansol, with Palæontological Description.

Part 2.—Obituary: Francis William Walker. Possibilities of finding concealed coal-field at a workable depth in Bombay Presidency. Basaltic Lavas penetrated by deep boring for coal at Bhusawal, Bombay Presidency.

Part 3.—Mineral Production of India during 1924. Enstatite-Augite Series of Pyroxenes. Constitution of the Glauconite and Celadonite. Palagonite-bearing Dolerite from Nagpur.

Part 4.—Fossiles Crétacés de l'Afghanistan. Fossiles du Kashmir et des Pamirs. Additions and Corrections to Vredenburg's Classification of the Cypræidæ. Petrology of Rocks from Girnar and Osham Hills, Kathiawar, India.

VOL. LIX, 1926-27.

Part 1.—General Report for 1925. Foraminifera of parts of Western India.

Part 2.—Sampling Operations in Pench Valley Coal-field. Composition of some Indian Garnets. Geology of Andaman and Nicobar Islands, with special reference to Middle Andaman Island. Occurrence of Cryptohalite. Remarks on Carter's Genus Conulites.

Part 3.—Mineral Production of India during 1925. Metamorphic Rocks and Intrusive Granite of Chhota Udepur State. Indian Species of Conoclypeus.

Part 4.—Low-Phosphorus Coking Coal in Giridih Coal-Field. Distribution of Gault in India. Age of so-called Danian Fauna from Tibet. Bauxite on Korlapat Hill, Kalahandi State, Bihar and Orissa.

VOL. LX, 1927-28.

Part 1.—General Report for 1926. Six Recent Indian Aerolites.

Part 2.—Gas Eruption on Ramri Island, off Aracan Coast of Burma, in July, 1926. Oil Indications at Drigh Road near Karachi. Lower Canine of Tetraconodon. Geology of Bundi State, Rajputana.

Part 3.—Mineral Production of India during 1926. Geological Traverse in Yunzalin Valley. Ambala Boring of 1926-27. Indian Unionidæ

Part 4.—Relationship between Specific Gravity and Ash Contents of Coals of Korea and Bokaro Coals as Colloid Systems. Contact of Basalt with coal-seam in the Isle of Skye, Scotland. Comparison with Indian examples. Barakar-Ironstone Boundary near Begunia, Raniganj Coal-field. Raniganj-Panchet Boundary near Asansol, Raniganj Coal-field. Permo-Carboniferous Marine Fauna from Umaria Coal-field. Geology of Umaria Coal-field, Rewah State, Central India. Composition and Nomenclature of Chlorophæite and Palagonite, and Chlorophæite Series. Miscellaneous Notes.

VOL. LXI, 1928-29.

Part 1.—General Report for 1927. Actinodon risinensis in Lower Gondwanas of Vihi district, Kashmir. Miscellaneous Note: Further Note on Nomenclature of Hollandite.

Part 2.—Contribution to Geology of Punjab Salt Range. Iron Ore Deposits of Northern Shan States. Lower Canine of Indian Species of Conohyus. Miscellaneous Note: Leucopyrite from Kodarma.

Part 3.—Mineral Production of India during 1927. Note on Coking Tests with Gondwana Coals. Zinc-Spinel, from Southern India. New Indian Meteorite: Lua Fall. Miscellaneous Note: Löllingite from Hazaribagh District.

Part 4.—Erratics of the Punjab. Cretaceous Dinosaurs of Trichinopoly District, and Rocks associated with them. Orbitolinæ from Tibet. Joya Mair Dome Fold, near Chakwal, Jhelum District, Punjab. Allophane at Tikak, Assam. Miscellaneous Note: Australian Species of Genus *Gisortia.*

VOL. LXII, 1929-30.

Part 1.—General Report for 1928. Miscellaneous Note: New Chromite Localities.

Part 2.—Obituary: Sivarau Sethu Rama Rau. Specific Gravity and Proximate Composition of Indian Vitrains. New Devonian Fossils from Burma. Rangoon Earthquakes of September and December 1927. Epicentre of North-West Himalayan Earthquake of 1st February 1929. Miscellaneous Notes: Indian Beryl, Atacamite in Bihar and Pyromorphite in Bhagalpur district, Bihar.

Part 3.—Mineral Production of India during 1928. Granophyric Trachyte from Salsette Island, Bombay. Coal Resources of the Jharia Coal-field. Coal lost by Fires and Collapses in Indian Coal Mines.

Part 4.—Age of Aravalli Range. Lake's Rule for angle of Overthrust, as applied to Himalayas. Permo-Carboniferous Succession in Warcha Valley, Western Salt Range, Punjab. Naoki (Hyderabad) Meteorite Shower of 29th September 1928. Miscellaneous Notes: Boring for water at Daryapur and Fossil Eggs at Yenangyaung, Upper Burma.

VOL. LXIII, 1930.

Part 1.—General Report for 1929. Upper Triassic Fossils from Burmo-Siamese Frontier.—Thaungyin Trias and Description of Corals. Upper Triassic Fossils from Burmo-Siamese Frontier.—Brachiopoda and Lamellibranchia from Thaungyin River. Upper Triassic Fossils from Burmo-Siamese Frontier.—Fossils from Kamawkala Limestone. Upper Triassic Fossils from Burmo-Siamese Frontier.—New Dasycladacea, *Holosporella siamensis* nov. gen., nov. sp., with Description of Allied Genus *Aciculella* Pia. Cretaceous Cephalopods in 'Red Beds' of Kalaw, Southern Shan States, Burma.

Part 2.—Methods of Analysis of Coal used at Government Test House, Alipore, Calcutta, with an Editorial Introduction. New fossil localities within Panchet series of Raniganj Coal Field. Species of *Cyllene* from Pegu Beds of Burma. Two new species of *Unio*. Glaciers of Karakoram and Neighbourhood. Miscellaneous Note: Dome near Mari in Attock district.

Part 3.—Mineral production of India during 1929. Specific Gravity and Proximate Composition of some Indian Durains.

Part 4.—Aspects of Modern Oil Field Practice. Undescribed freshwater Molluscs from various parts of India and Burma. Second note on North-West Himalayan Earthquake of 1st February, 1929. Miscellaneous Notes: Tremolite from near Jasidih, Bihar, Sapphirine in Vizagapatam District and Titaniferous Augite from Chandrawati, Sirohi State, Rajputana.

VOL. LXIV, 1930.

Quinquennial Review of Mineral Production of India for 1924-1928. Price 9 Rs. 6 As.

VOL. LXV, 1931.

Part 1.—General Report for 1930. Additional Note on Samelia Meteorite. Zoning and Difference in Composition of Twinned Plagioclase Felspars in certain rocks from Sirohi State, Rajputana. Albite-Ala B Twinning of Plagioclase Felspars in certain acidic rocks from Sirohi State, Rajputana. Jurassic Fossils from Northern Shan States.

Part 2.—Syntaxis of North-West Himalayas: Its Rocks, Tectonics and Orogeny. Preliminary Note on Pegu Earthquake of May 5th, 1930. Determination from World Records of Zero-time and Epicentre of Pegu Earthquake of May 5th, 1930. Long Distance Wave Speeds of Pegu Earthquake of May 5th, 1930. Rocks bearing Kyanite and Sillimanite in Bhandara District, C. P. Stratigraphy of Upper Ranikot Series (Lower Eocene) of Sind, India. Miscellaneous Note:—Fuchsite vase from Mohenjo Daro (Sind).

Part 3.—Mineral Production of India during 1930. Geology and Lead-ore Deposits of Mawsön, Federated Shan States. Weathering of Vindhyan Building Stone. *Maclurites* from Ordovician of Burma. Miscellaneous Notes: Supplementary note on 'Revisions of Indian Fossil Plants, Part II Coniferales (b. Petrifactions), 1931' and Eruption of Mud Volcano off Arakan Coast.

Contents and index to Records, Vols. I-XX and Vols. XXI-XXX. Price 1 rupee each.

The price fixed for these publications is 1 rupee each part, or 2 rupees each volume of four parts, and the price of each part beginning with Vol. LIV is Rs. 2-12-0, or each volume of four parts Rs. 11.

MISCELLANEOUS PUBLICATIONS.

A Manual of the Geology of India. 4 Vols. With map, 1879-1887—
Vol. 1. Peninsular Area. } By H. B. Medlicott and W. T. Blanford.
Vol. 2. Extra Peninsular Area. } Price 8 rupees (*out of print*).
Vol. 3. Economic Geology. By V. Ball. Price 5 rupees (*out of print*).
Vol. 4. Mineralogy. By F. R. Mallet. Price 2 rupees (*out of print*).

A Manual of the Geology of India, 2nd edition. By R. D. Oldham (1893). Price 8 rupees (*out of print*).

A Manual of Geology of India, Economic Geology by the late Prof. V. Ball, 2nd edition, revised in parts—
Part I.—Corundum. By T. H. Holland (1898). Price 1 rupee.

An introduction of the Chemical and Physical study of Indian Minerals. By T. H. Holland (1895). Price 8 annas (*out of print*).

Popular guides to the Geological collection in the Indian Museum, Calcutta—
No. 1. Tertiary vertebrate animals. By R. Lydekker (1879). Price 2 annas (*out of print*).
No. 2. Minerals. By F. R. Mallet (1879). Price 2 annas (*out of print*).
No. 3. Meteorites. By F. Fedden (1880). Price 2 annas (*out of print*).
No. 4. Palæontological collections. By O. Feistmantel (1881). Price 2 annas.
No. 5. Economic mineral products. By F. R. Mallet (1883). Price 2 annas (*out of print*).

A descriptive catalogue of the collection of minerals in the Geological Museum. By F. R. Mallet (1883). Price 1 rupee 8 annas.

Catalogue of the remains of Siwalik Vertebrata contained in the Geological Department of the Indian Museum. By R. Lydekker, Pt. I. Mammalia (1885). Price 1 rupee. Part II, Aves, Reptilia, and Pisces (1886). Price 4 annas.

Catalogue of the remains of Pleistocene and Pre-Historic Vertebrata contained in the Geological Department of the Indian Museum. By R. Lydekker (1886). Price 4 annas.

Bibliography of Indian Geology. By R. D. Oldham (1888). Price 1 rupee 8 annas.

Bibliography of Indian Geology. By T. H. D. LaTouche—
Part I-A. Bibliography (1917). Price 4 rupees.
Part I-B. Index of minerals of Economic Value (1918). Price 4 rupees.
Part II. Index of Localities (1921). Price one rupee.
Part III. Index of Subjects (1923). Price 4 rupees.
Part IV. Palæontological Index (1926). Price 7 rupees 4 annas.

Report on the geological structure and stability of the hill slopes around Naini Tal. By T. H. Holland (1897). Price 3 rupees.

Geological map of India, 1893. Scale 1″ = 96 miles. Price 1 rupee (*out of print*).

Geological Map of India, in 8 sheets, 1931. Scale 1″ = 32 miles. Price 16 rupees per set, or Re. 1 to Rs. 5 per sheet depending on the amount of work on the sheet.

Geological map of Tavoy district, Burma, 1919. Scale 1″ = 4 miles. Price 5 rupees.

Geological map of Bihar and Orissa, 1922. Scale 1″ = 16 miles. Price 5 rupees.

Geological map of Jharia Coal-field, in 8 sheets, 1929. Scale 4″ = 1 mile. Price 4 rupees per sheet, or 25 rupees per set of 8 sheets and 3 plates of bore-hole records.

Geological map of Raniganj Coal Field, in 21 sheets, 1930. Scale 4″ = 1 mile. Price 4 rupees per sheet, or 65 rupees per set of 21 sheets and 3 plates of bore-hole records.

General Report for the period from 1st January 1897 to 1st April 1898. Price 1 rupee (*out of print*).

General Report for the year 1898-1899. Price 1 rupee (*out of print*).

General Report for the year 1899-1900. Price 1 rupee.

General Report for the year 1900-1901. Price 1 rupee.

General Report for the year 1901-1902. Price 1 rupee.

General Report for the year 1902-1903. Price 1 rupee.

Sketch of the Mineral Resources of India. By T. H. Holland (1908). Price 1 rupee (*out of print*).

Contents and index to Records, Vols. I-XX and Vols. XXI-XXX. Price 1 rupee each.

Contents and index to Memoirs, Vols. I-XX and Vols. XXI-XXXV. Price 1 rupee each.

Index to the Genera and Species described in the Palæontologia Indica, up to the year 1891. Price 1 rupee.